CCS Site Characterization Program

Characterization of Most Promising Carbon Capture and Sequestration Formations in the Central Rocky Mountain Region (RMCCS)

Acknowledgements

• Many thanks to the U.S. Department of Energy and NETL for supporting this project

• We express our gratitude also to our many industry partners, who have committed a great deal of time, funding and other general support for these projects

• The work presented today is co-authored by Brian McPherson and Vince Matthews, with contributions from many partners in the RMCCS project

Presentation Outline

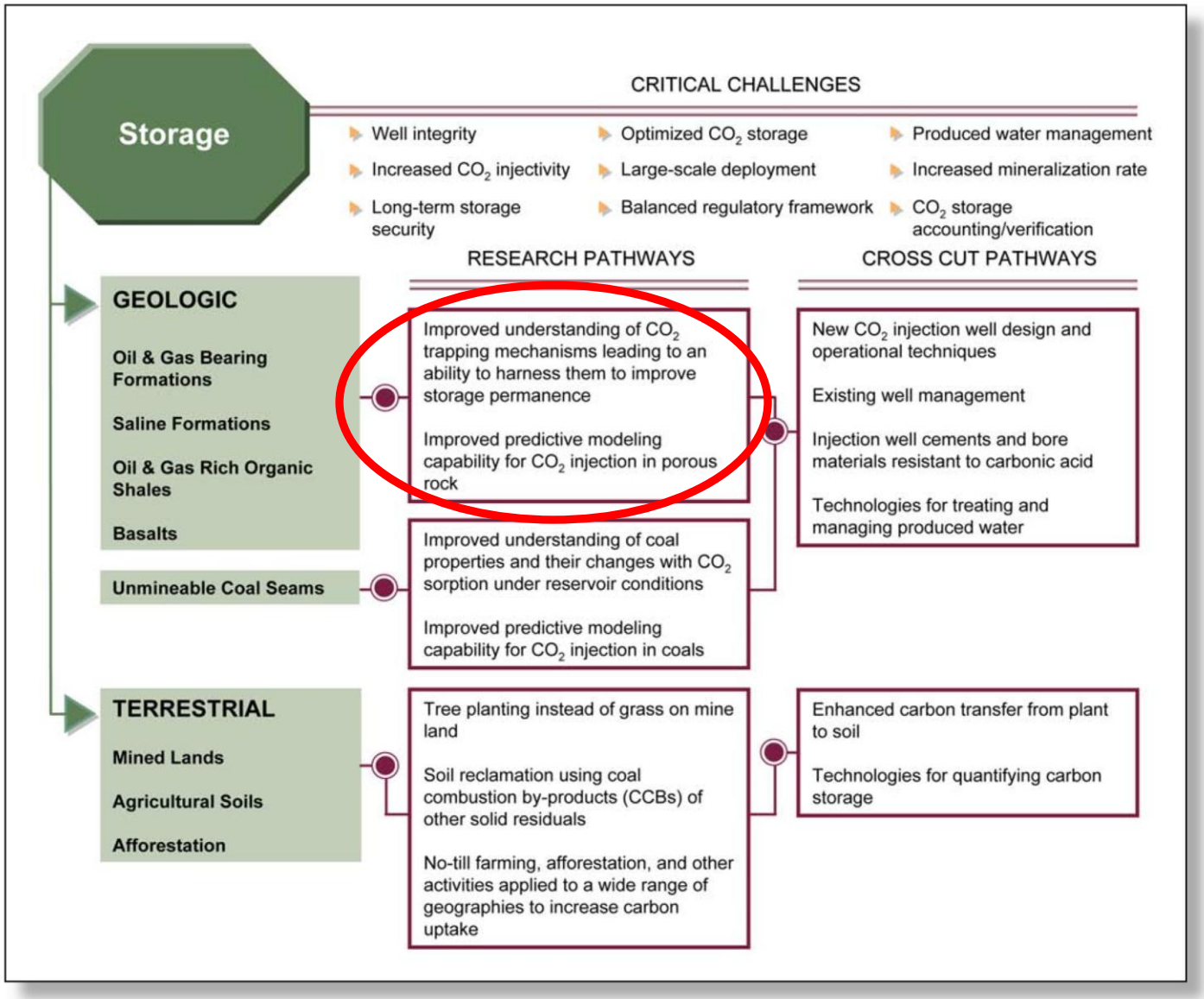
- Major Goals and Context (Why)
- Outcomes and Deliverables (What)
- Project Team and Plan (How)
- Budget and Cost-Share

Major Goals and Context

Broad Goals: "The goals are focused on *reservoir characterization, storage potential*, and large-scale injection, which are tied directly to the Program goal of achieving 99 percent storage permanence."

- NETL Carbon Sequestration Technology Roadmap and Program Plan

Major Goals and Context



Major Goals and Context

Regional Goal: Thoroughly characterize the most promising geologic storage targets within the southwestern U.S. and the Central Rocky Mountain region in particular.

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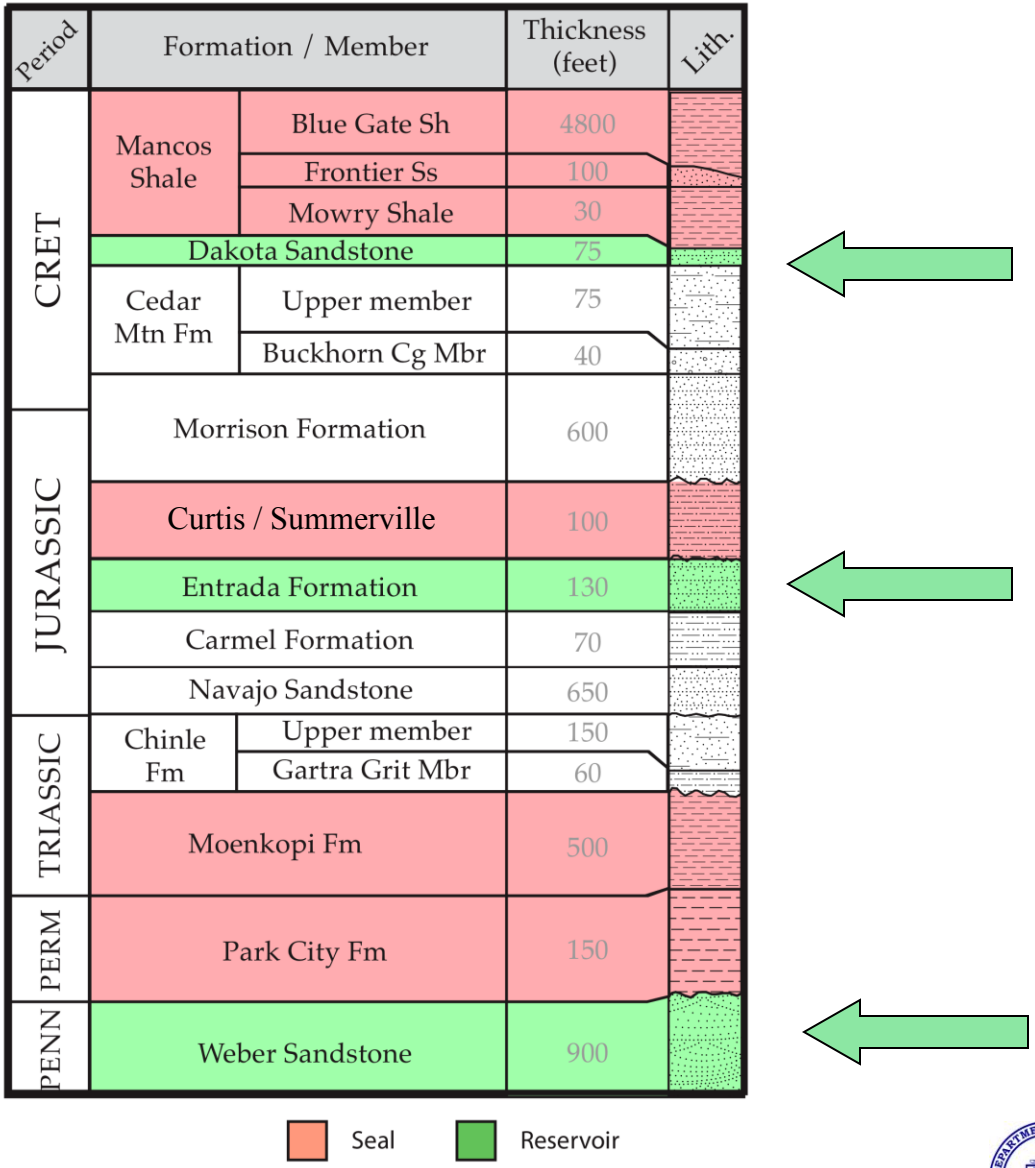

Major Goals and Context

Some Specific Technical Goals:

(1) optimization of capacity estimation

(2) optimization of monitoring design - especially effective spatial coverage and survey/measurement frequency

(3) optimization of simulation models - especially alignment of spatial and temporal scales of models with those of monitoring technologies

(4) optimization of risk assessment

We anticipate that explicit focus on improving characterization methodologies can create major improvements of these four critical CCS activities.

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Expected Outcomes

First and foremost, the tasks, major activities, and deliverables:

Task 1.0 Project Management
- Updated Project Management Plan
- NEPA and permitting
- Education and Outreach begins
- Copies of all permits, including summary topical report of acquisition protocols

Task 2.0 Assess Regional Significance of the Dakota, Entrada, and Weber Formations
- Gather all available data, esp. but not limited to public information
- Regional Models and Analyses
- Evaluate Regional Capacity and Significance (Topical Report)
- Update national databases

Task 3.0 Site-Specific Evaluation of the Dakota, Entrada, and Weber Formations
- Drill, Log and Core Deep Well
- Evaluate and Report Sequestration Capacity of Most Promising Formations (Topical Report)
- Develop and Apply Simulation Model Analysis of Most Promising Formations

Task 4.0 Conduct Risk Assessment
- Risk Registry for Case Study Site
- Evaluate and Report on Risk Assessment and Mitigation Strategies (Topical Report)

Task 5.0 Final Site Characterization Plan and Protocols
- Finalize Characterization of Most Promising CCS Geologic Formations (Topical Report)
- Final Site Characterization Plan and Protocols Document (Formal and Published)

Task 6.0 Develop a well bore management and mitigation strategy
- Same deliverables as listed under task 4

Task 7.0 Optimize Reservoir Engineering to Maximize CO_2 Injection/Produced Fluid Beneficial Use
- Develop and Report on Reservoir Engineering Optimization Strategies (Topical Report)

Expected Outcomes

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Expected Outcomes

Some Critical Technical Goals and Outcomes:

- optimization of capacity estimation

Expected Outcomes

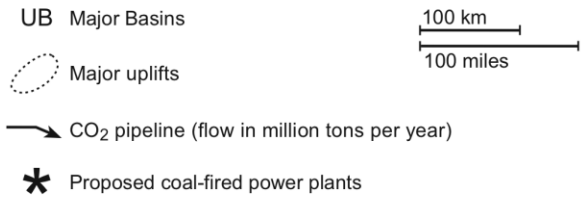
Optimize Capacity Estimation: Number of Years for Specific Sources

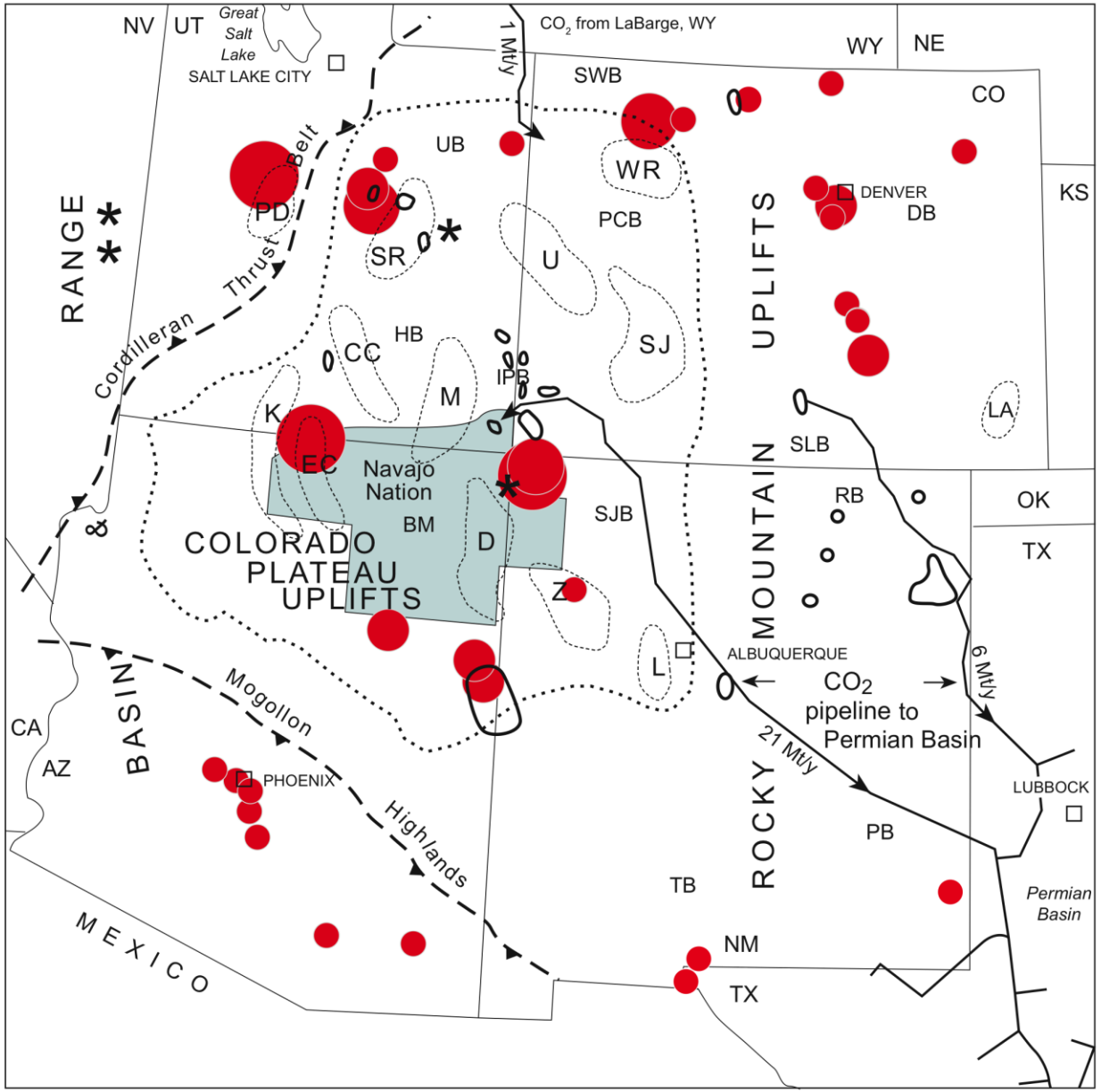
Annual mass of CO_2 emissions from power plants, in million tons per year (Mt/y)

EXAMPLE: Regional Emissions

Point Sources :

~318 million tons CO_2 per year





Expected Outcomes

Case Study Area

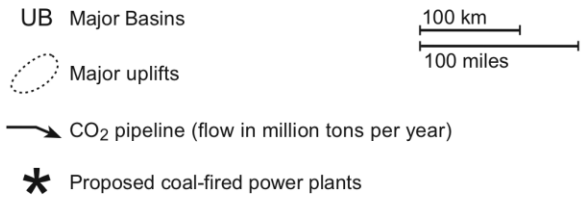
Optimize Capacity Estimation: Number of Years for Specific Sources

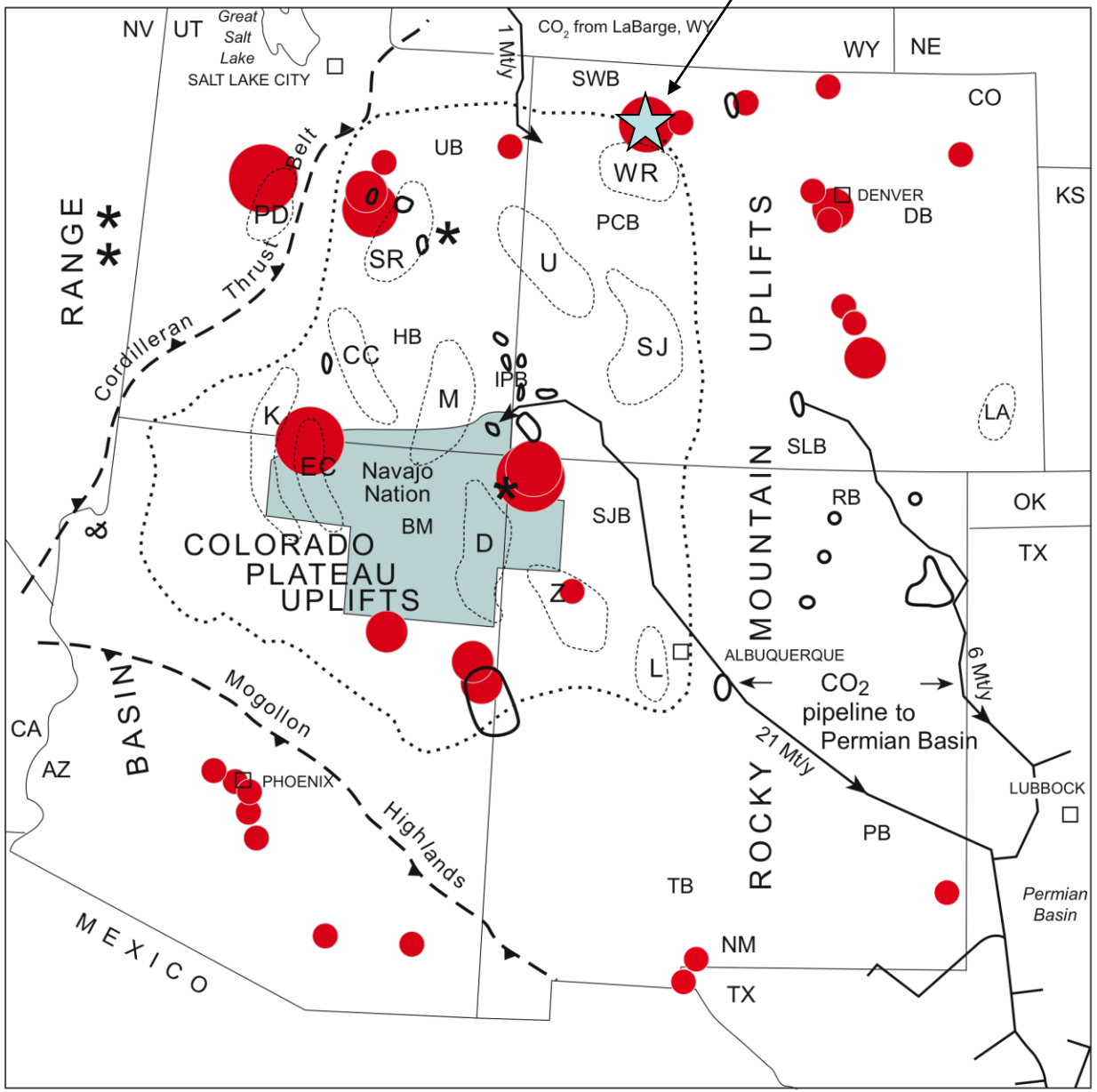
Annual mass of CO_2 emissions from power plants, in million tons per year (Mt/y)

EXAMPLE: Regional Emissions

Point Sources :

~318 million tons CO_2 per year





Expected Outcomes

Optimize Capacity Estimation: Number of Years for Specific Sources

From Atlas II:

Saline Formation CO_2 Storage Resource by State (million metric tons)		
State	**Low CO_2 Storage Resource**	**High CO_2 Storage Resource**
Arizona	199	752
Colorado	18,828	75,313
Kansas	8	9
Nebraska	87	348
New Mexico	33,054	132,215
Oklahoma	2	9
Texas	11,700	46,800
Utah	24,934	99,305
Wyoming	4,909	19,636

EXAMPLE: Regional Emissions Point Sources :

~318 million tons CO_2 per year

$$\frac{700{,}000\ million\ metric\ tons}{318\ million\ metric\ tons/yr}$$

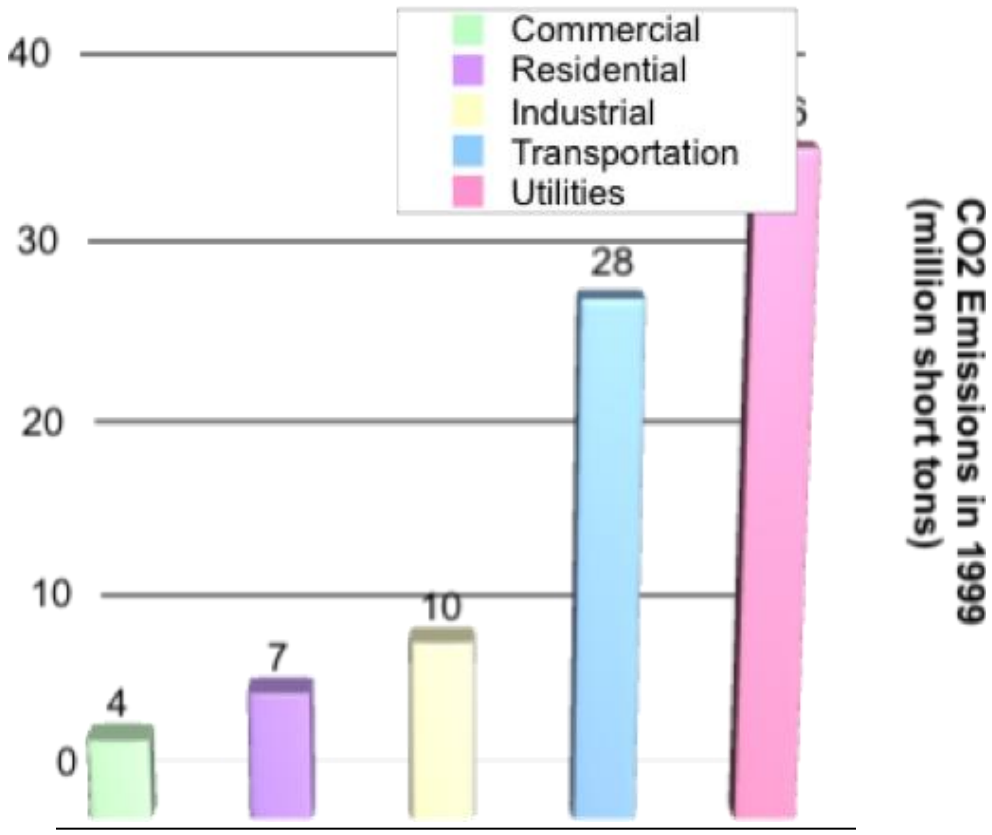
$$\approx 2{,}200\ years$$

Maximum estimated SW saline capacity: 700,000 million metric tons

Expected Outcomes

Optimize Capacity Estimation:
Number of Years for Specific Sources

Example: CO_2 Emissions in Colorado



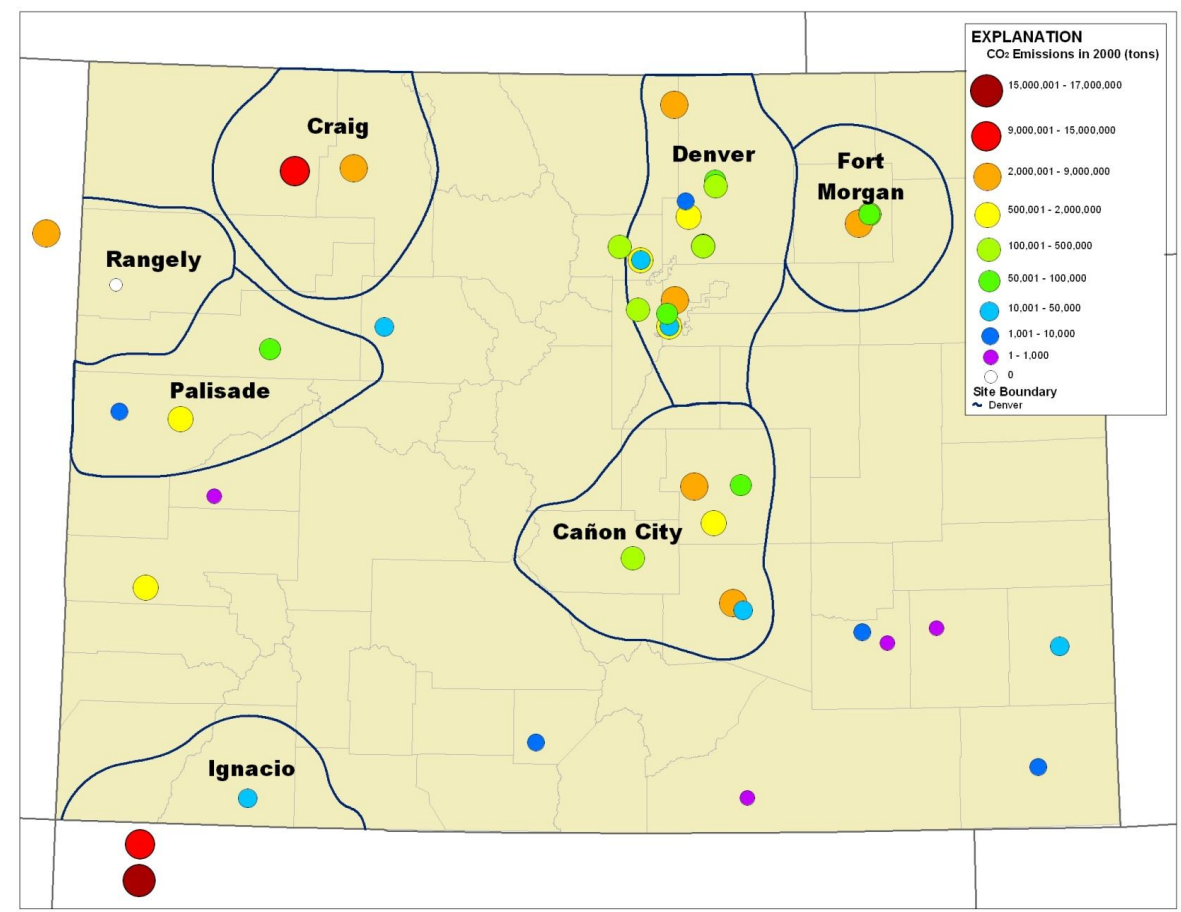
85 Mt total for 1999

from Vanessa Lintz, CGS

Expected Outcomes

Optimize Capacity Estimation: Number of Years for Specific Sources

Example: CO_2 Emissions in Colorado



Expected Outcomes

Optimize Capacity Estimation:
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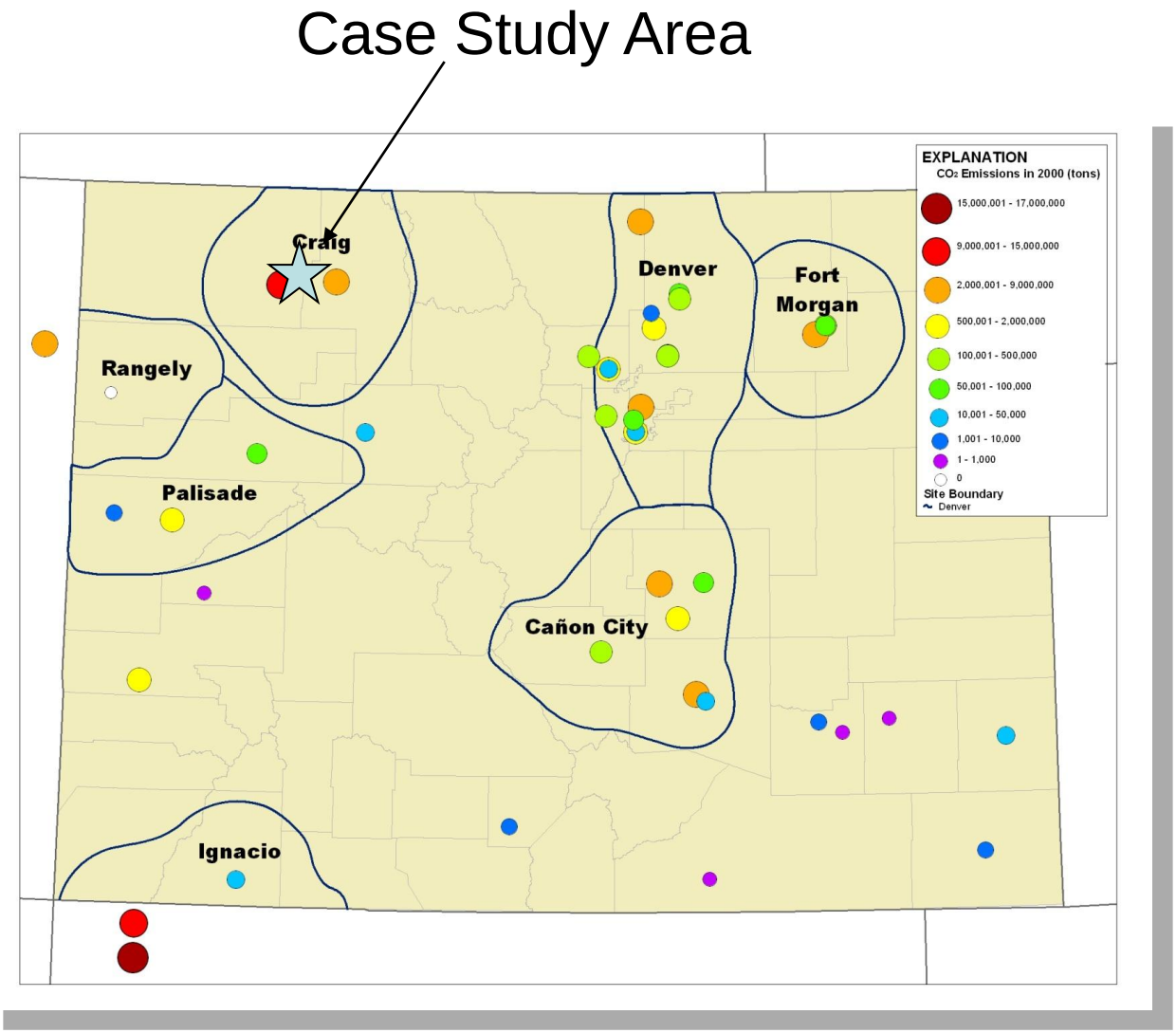

Expected Outcomes

Optimize Capacity Estimation: Number of Years for Specific Sources

Total Capacity Estimate:
(saline formations only)

$$\frac{680{,}000\ Mtons}{80\ Mtons/yr} \approx 8500\ years$$

Example: CO_2 Emissions in Colorado

2000 Emissions (Mt)		*Storage Capacity - New Estimates*		
		Oil & Gas	Coal Beds	Saline Aquifers
Canon City	9.4	0	493	122,118
Craig	14.4	123	11,059	46,209
Denver	14.1	557	602	129,138
Fort Morgan	4.1	164	0	43,700
Ignacio	31.5	186	2,809	92,142
Palisade	0.8	116	1,798	132,330
Rangely	3.4	740	1,037	102,579
Total	*~80*	*1,886*	*17,798*	*~680,000*

from Beth Widmann, CGS

Expected Outcomes

EXAMPLE: Utah Emissions & Capacity

Sources : ~35 million metric tons CO_2 per year

Utah's CO_2 Sinks and Capacities:

Saline Formation CO_2 Storage Resource by State (million metric tons)		
State	Low CO_2 Storage Resource	High CO_2 Storage Resource
Arizona	199	752
Colorado	18,828	75,313
Kansas	8	9
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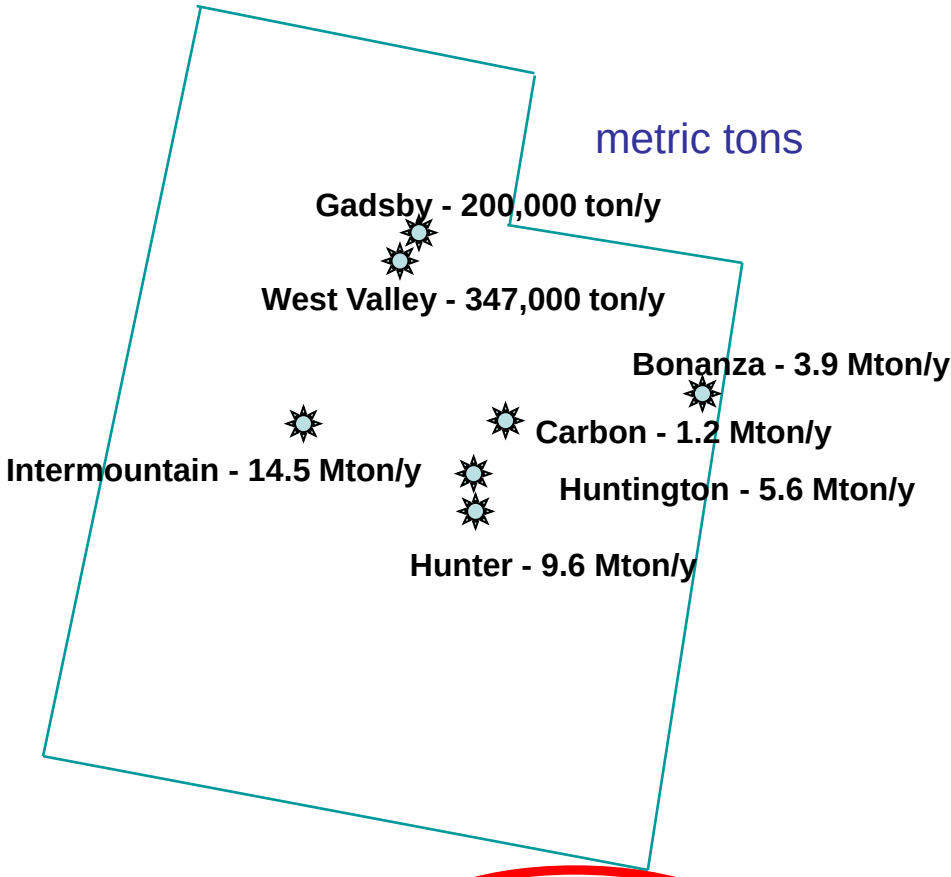


$$\frac{99{,}305\ Mtons}{35\ Mtons/yr} \approx 2800\ years$$

Expected Outcomes

While we can evaluate capacity (in years of emissions) based on broad and regional-scale characterization, site-specific analyses are hampered by the high cost of high resolution characterization.

The point: the uncertainty and regional nature of these capacity estimates (in years) are significant and can be reduced!

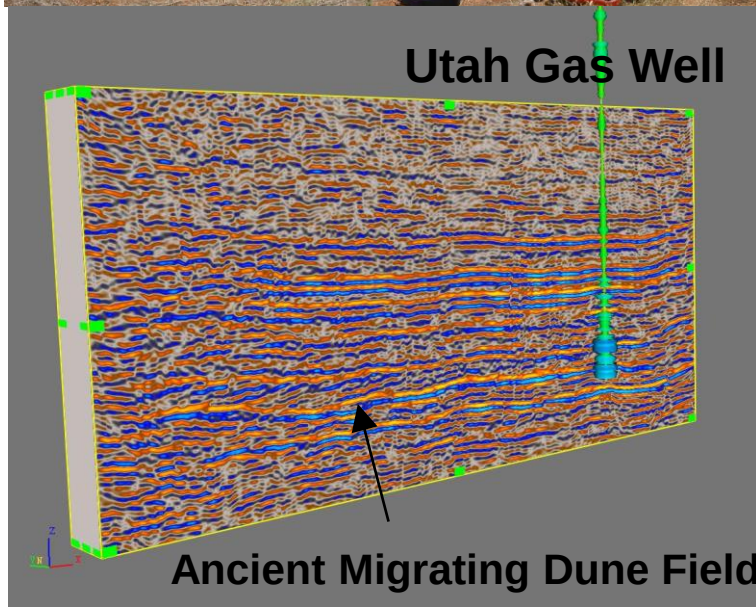
Expected Outcomes

Some Critical Technical Goals and Outcomes:

- optimization of capacity estimation
- optimization of monitoring design - especially effective spatial coverage and survey/measurement frequency

Expected Outcomes

Better Characterization Provides More Effective Monitoring Design



Monitoring for Detecting CO_2 in non-Targets:

- Groundwater chemistry (non-target reservoirs)
- Surface CO_2 chamber flux
- Shallow CO_2 “piezometers” for sub-bio flux
- Remote sensing / LandSat Imaging
- Coupled process reservoir modeling

Monitoring for Tracking CO_2 Migration and Fate

- 2-D and/or 3-D seismic reflection
- Vertical seismic profiles (VSP)
- Crosswell seismic imaging
- Passive seismic monitoring/imaging
- Groundwater chemistry (target reservoir)
- In situ pressure, temperature measurements
- In situ bicarbonate detection
- Coupled process reservoir modeling
- Microgravity surveys

Focus monitoring on: resolved risk FEPS or unresolved areas

Expected Outcomes

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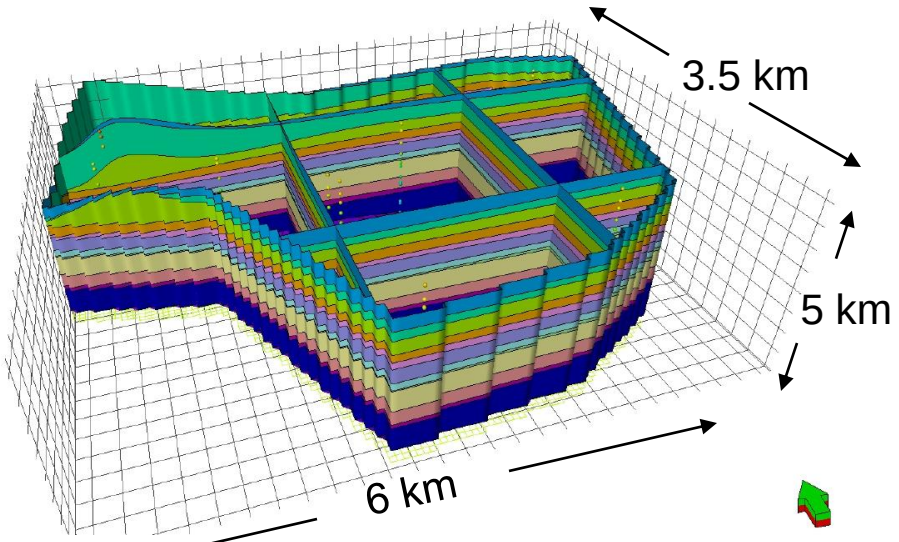
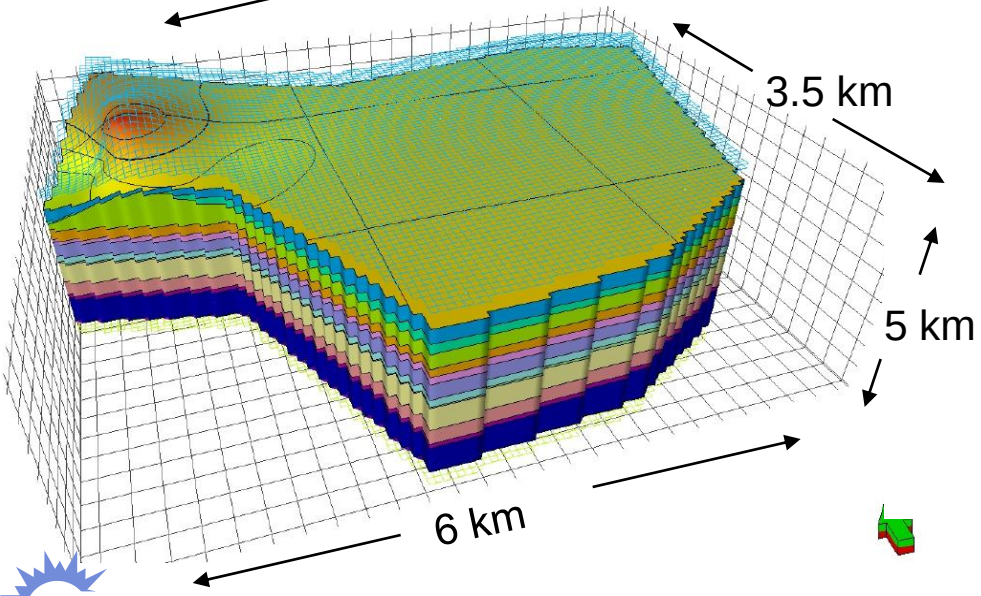
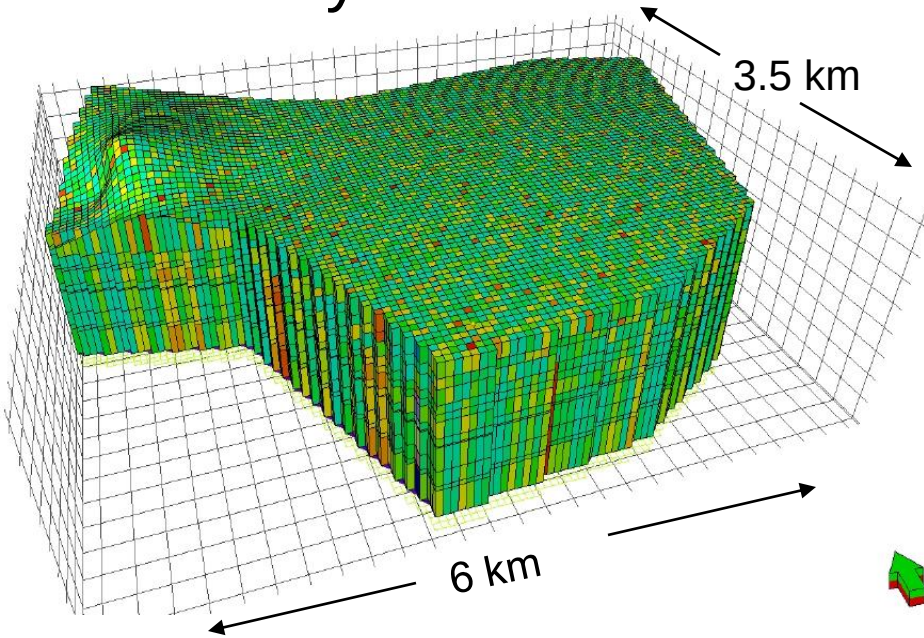




- spatial and temporal resolution of models **must** match resolution of monitoring technologies - better characterization will help dramatically!



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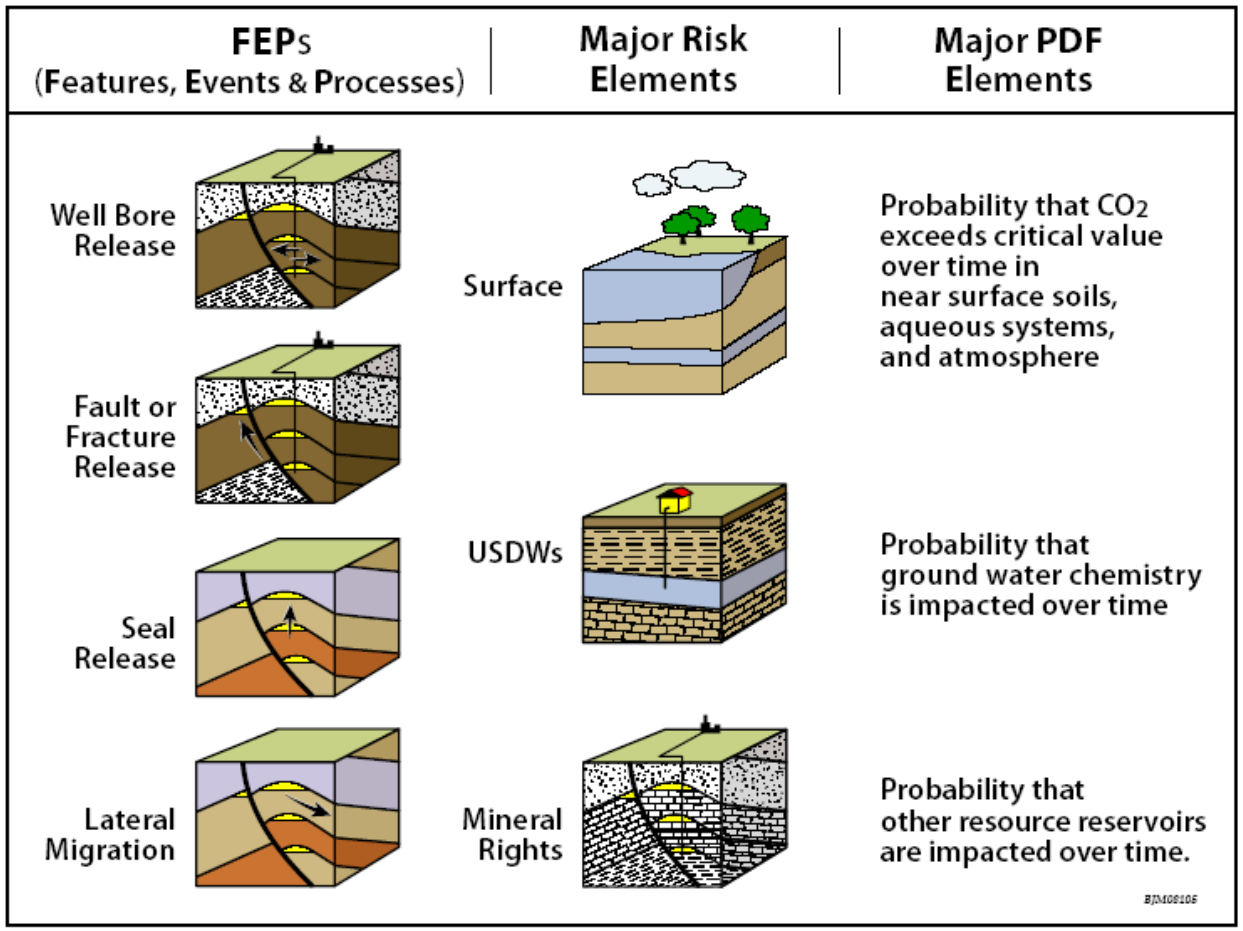

Modified from Guthrie et al.

- Improved site characterization = improved modeling, monitoring, and risk assessment

Top Goal and Deliverable

Top goal:

Based on a site-specific characterization of the case study site near Craig, CO, identify the most effective criteria for ranking potential storage sites throughout the region.

Top Deliverable:

Final Site Characterization Plan and Protocols, Including Site-Selection Criteria

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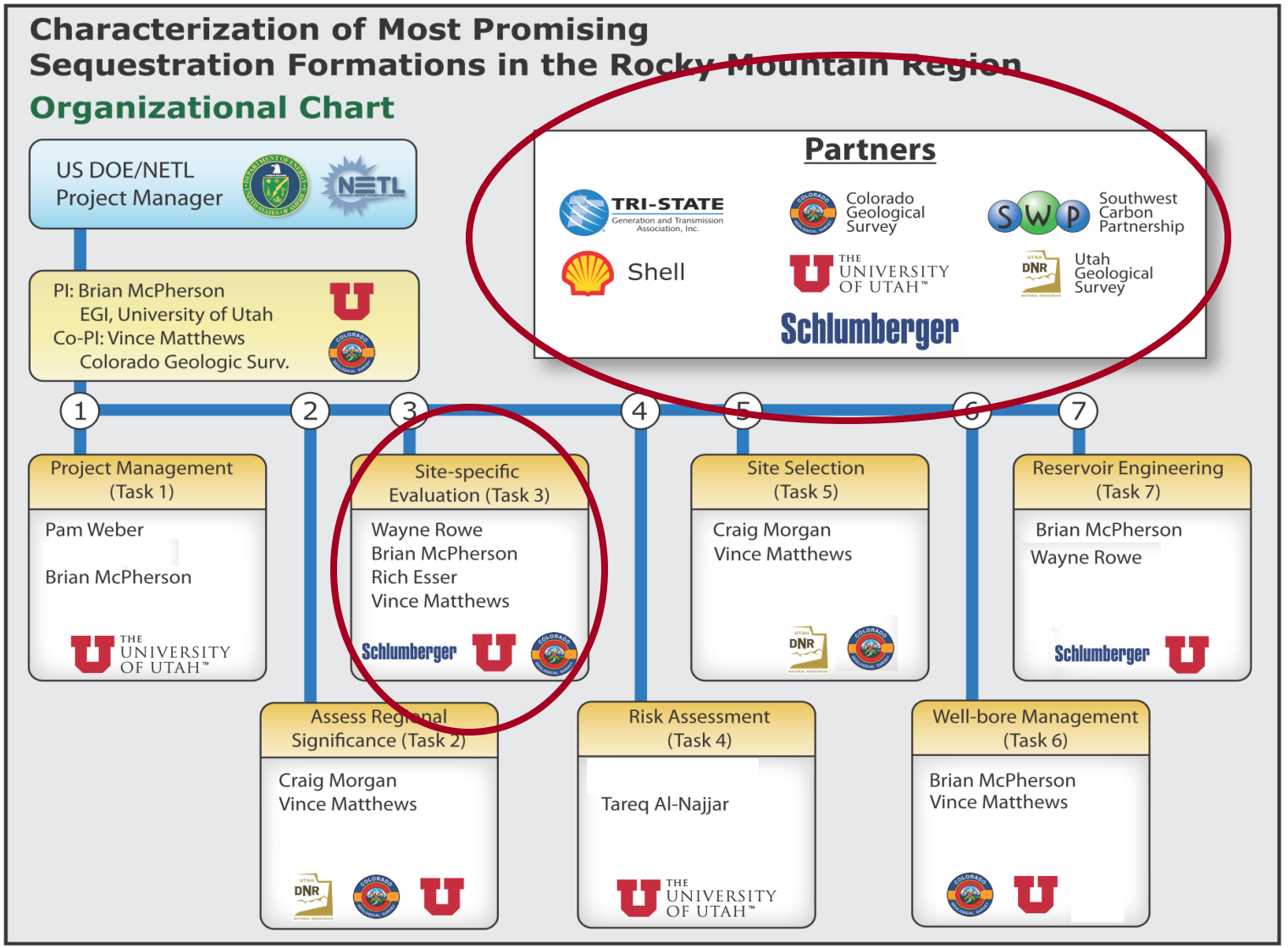
Project Team and Plan



The Plan – Year 1

- Characterize the Structure
  - Build database
  - Purchase seismic
  - Process & interpret seismic
  - Map surface structure
  - Shoot seismic line
- Pick location for drill hole
- Permit well

Regarding basic characterization, what do we know so far?

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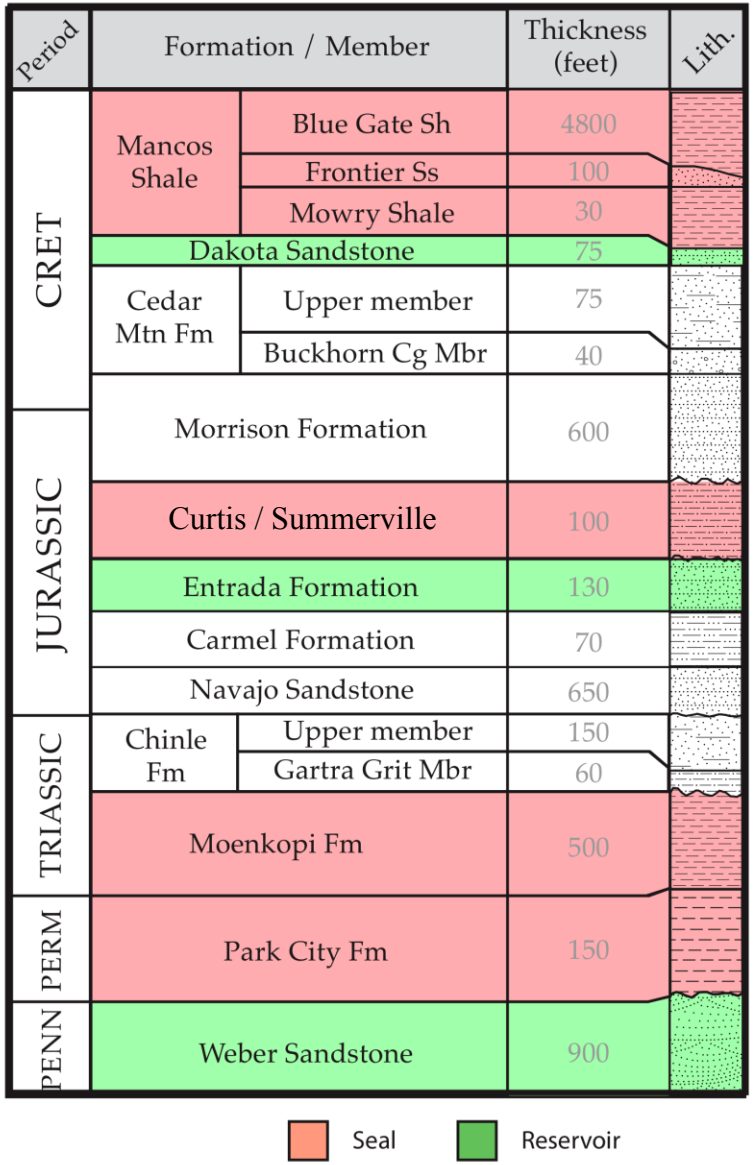
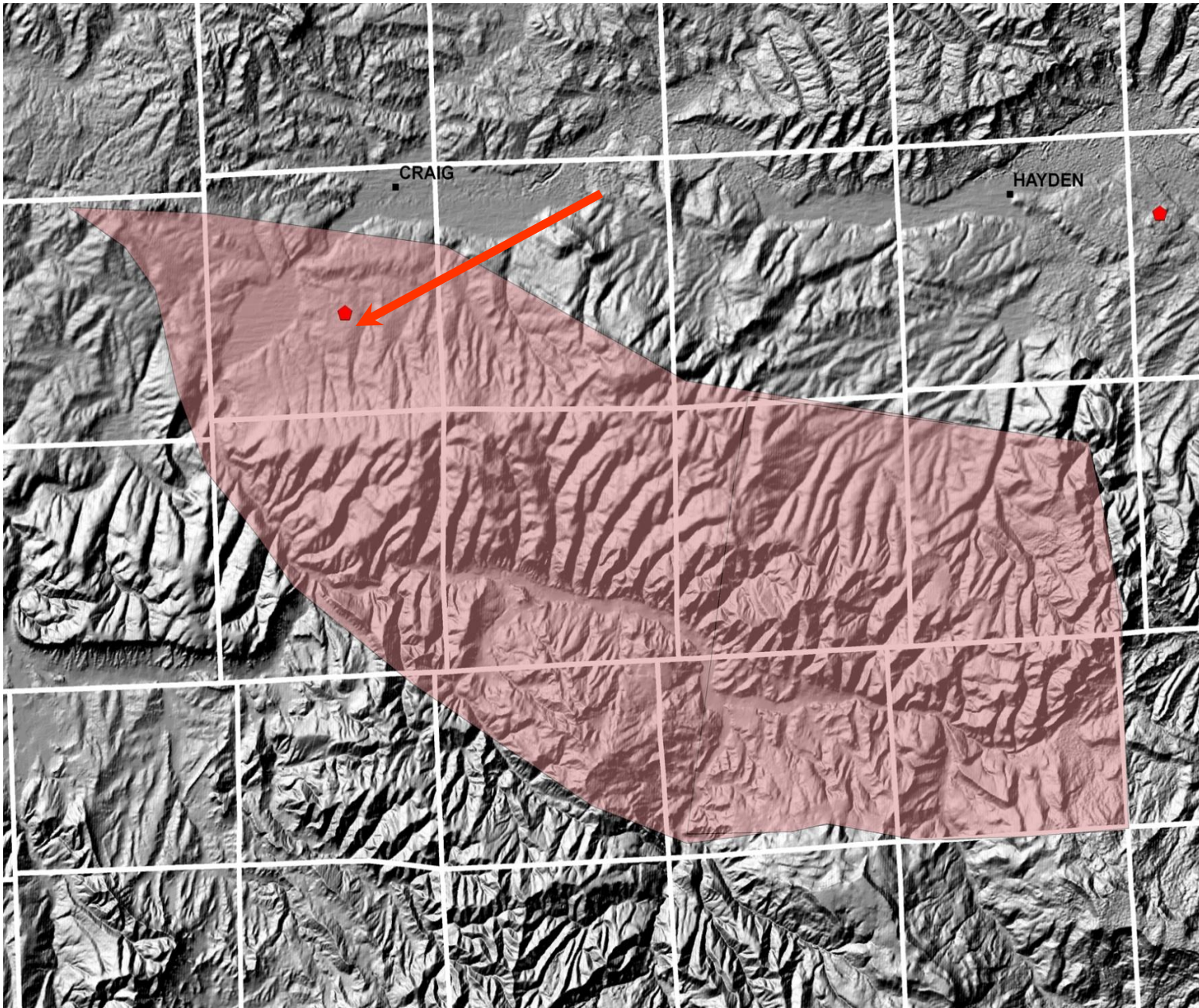
Using: Basic Stratigraphic Knowledge



What do we know so far?

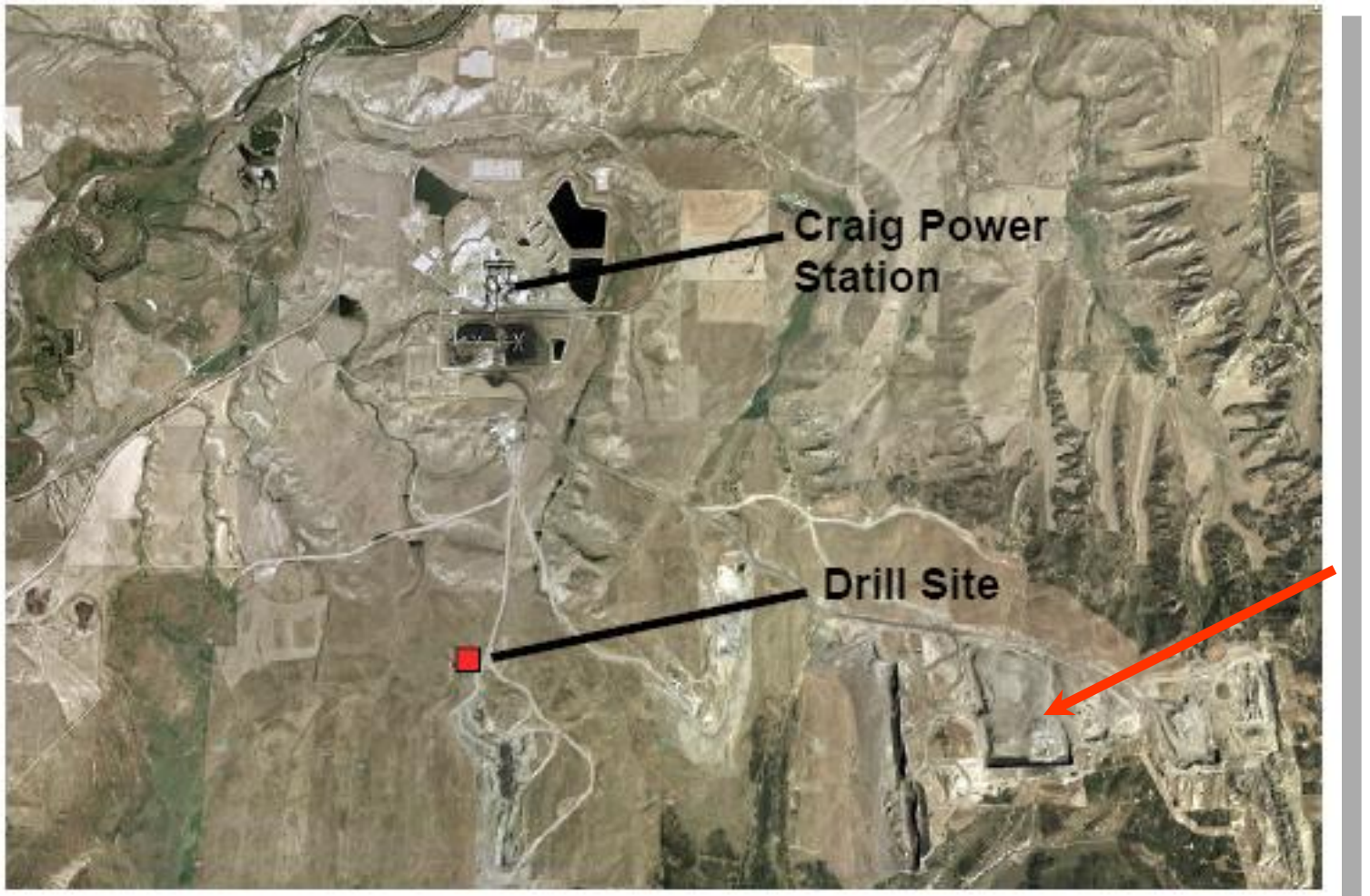
Using: DEMs

Pink = outline of Laramide "forced fold" structure



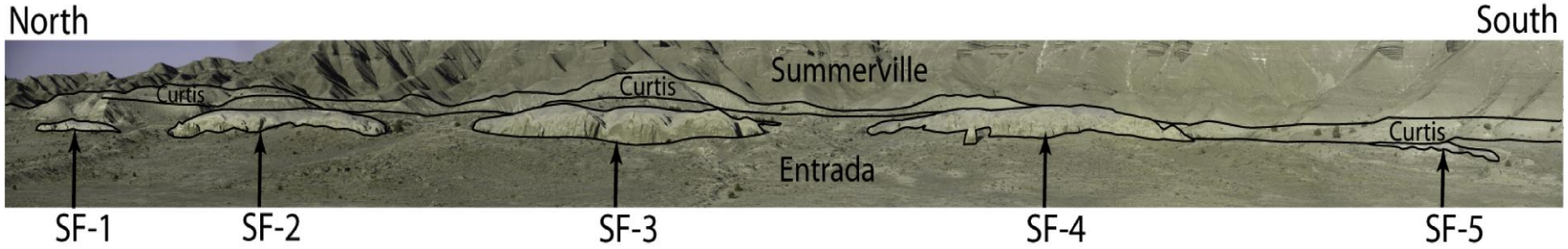
What do we know so far?

Using: Satellite Photos



What do we know so far?

Using: Outcrop Data



What do we know so far?

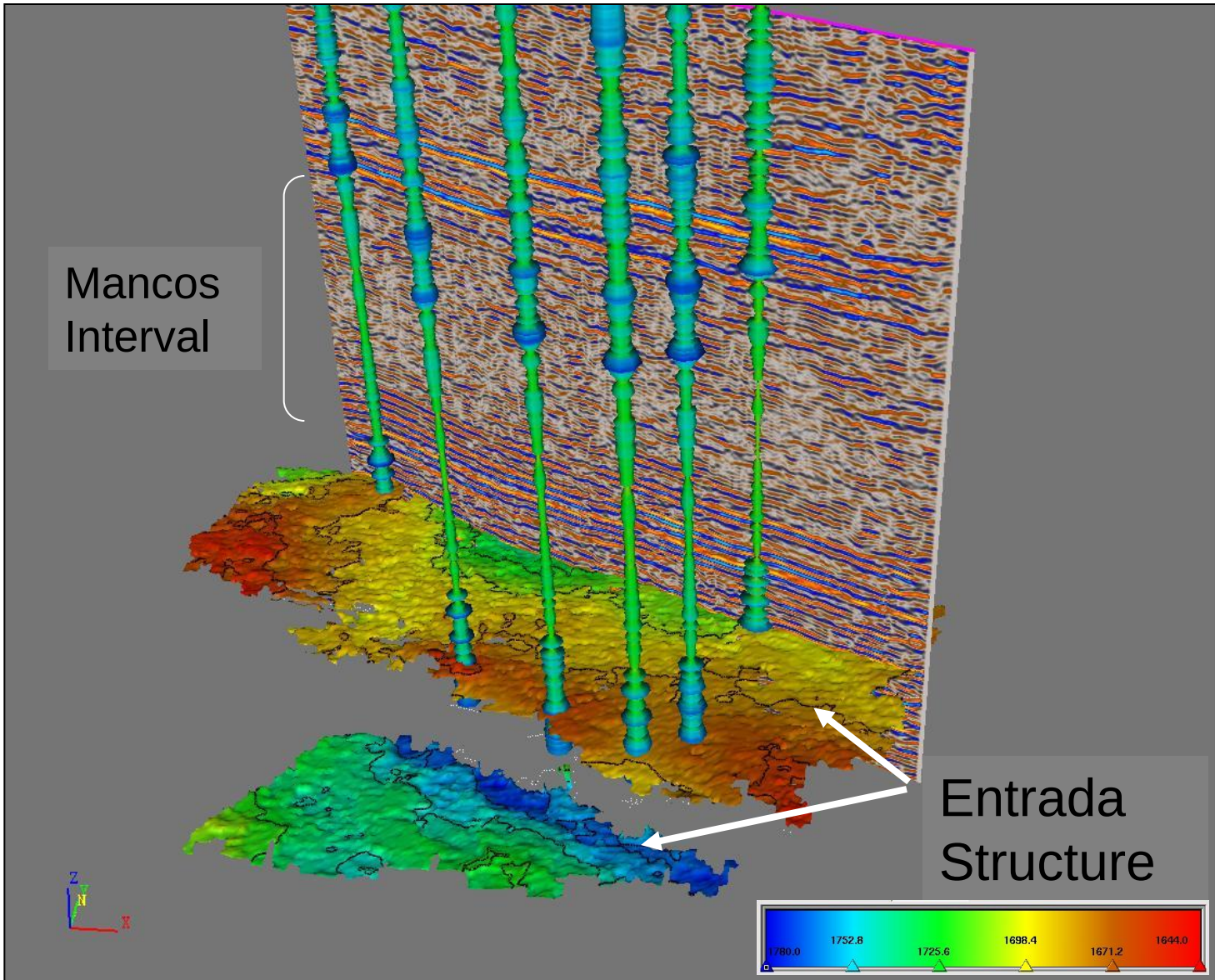
Using: Outcrop Data

Period	Formation / Member		Thickness (feet)	Lith.
CRET	Mancos Shale	Blue Gate Sh	4800	
		Frontier Ss	100	
		Mowry Shale	30	
	Dakota Sandstone		75	
	Cedar Mtn Fm	Upper member	75	
		Buckhorn Cg Mbr	40	
JURASSIC	Morrison Formation		600	
	Curtis / Summerville		100	
	Entrada Formation		130	
	Carmel Formation		70	
	Navajo Sandstone		650	
TRIASSIC	Chinle Fm	Upper member	150	
		Gartra Grit Mbr	60	
	Moenkopi Fm		500	
PERM	Park City Fm		150	
PENN	Weber Sandstone		900	

Seal Reservoir

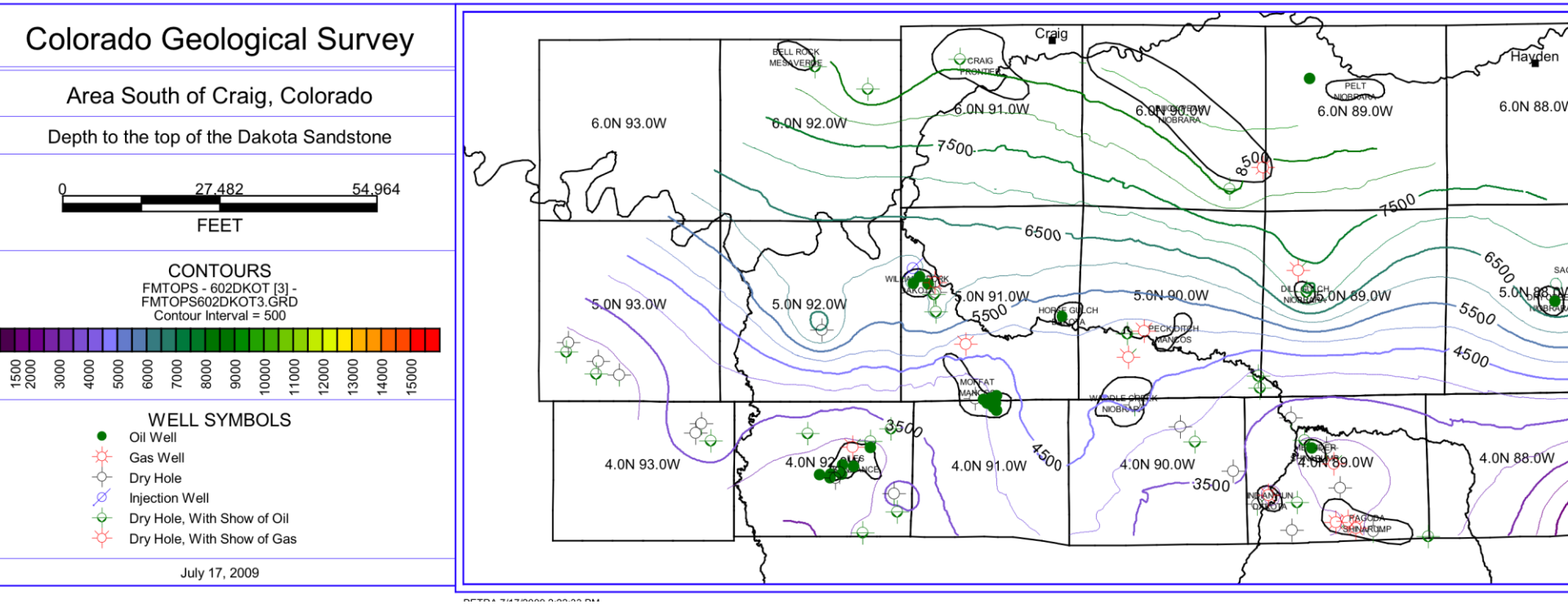
What do we know so far?

Using: Log Data



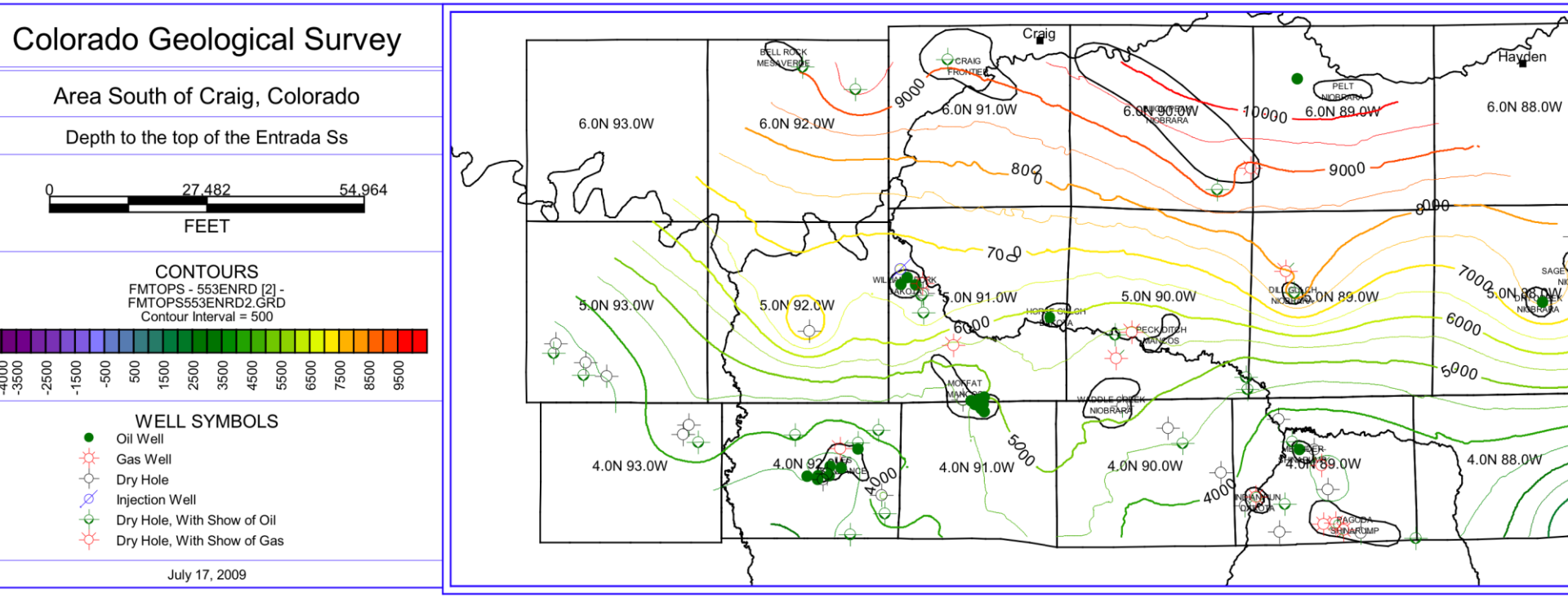
What do we know so far?

The team then: developed structure maps of the Dakota



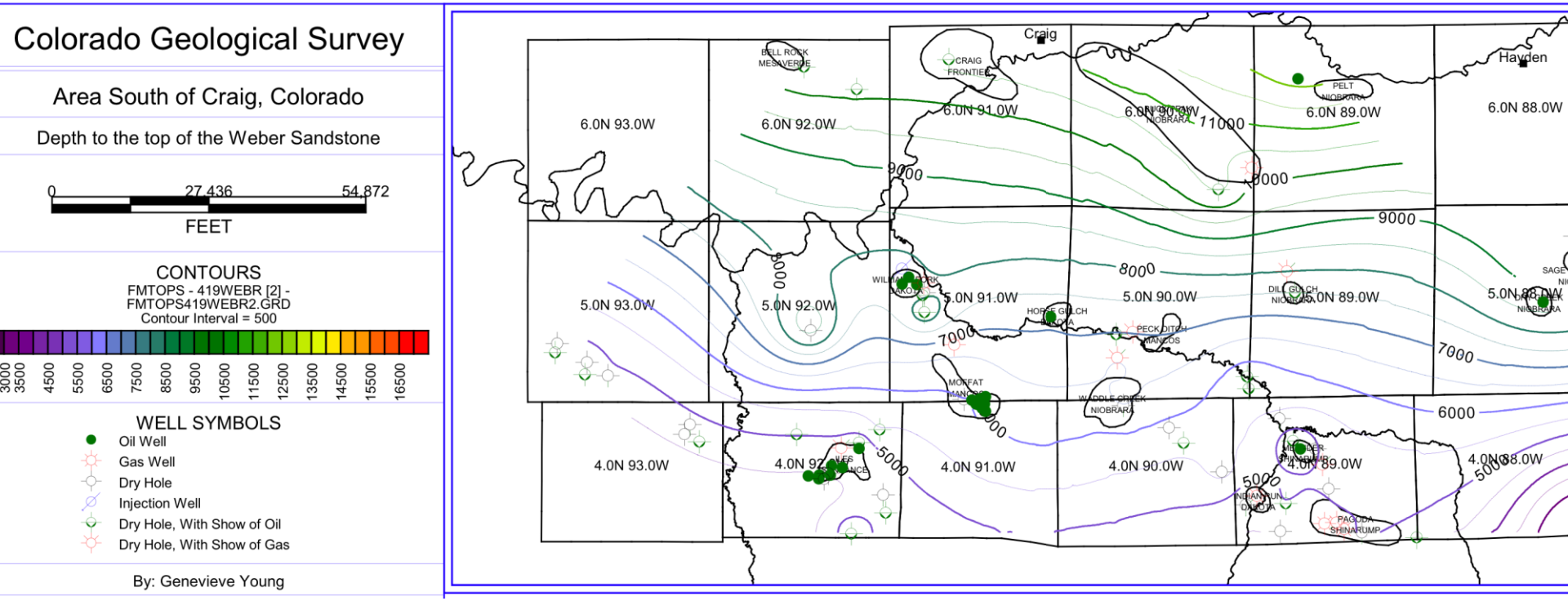
What do we know so far?

The team then: developed structure maps of the Entrada



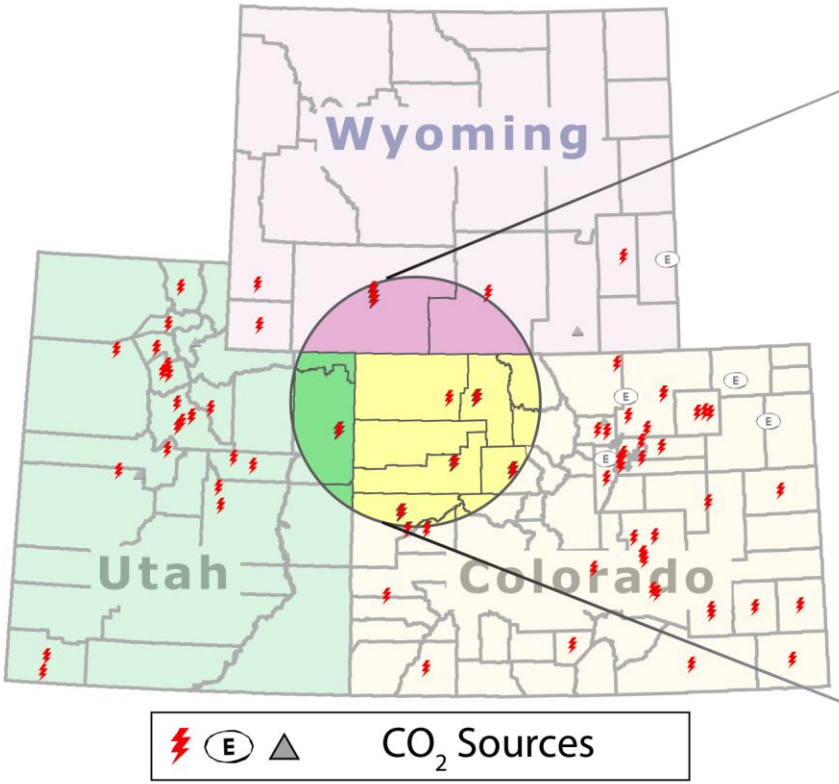
What do we know so far?

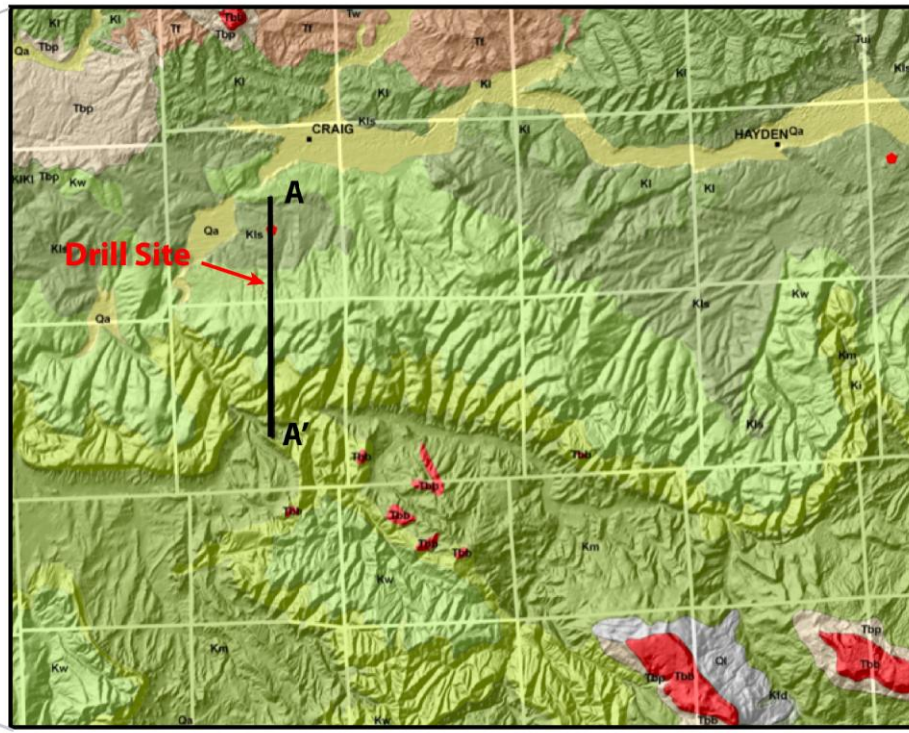
The team then: developed structure maps of the Weber



What do we know so far?

We also: picked tentative drill sites and transects to evaluate





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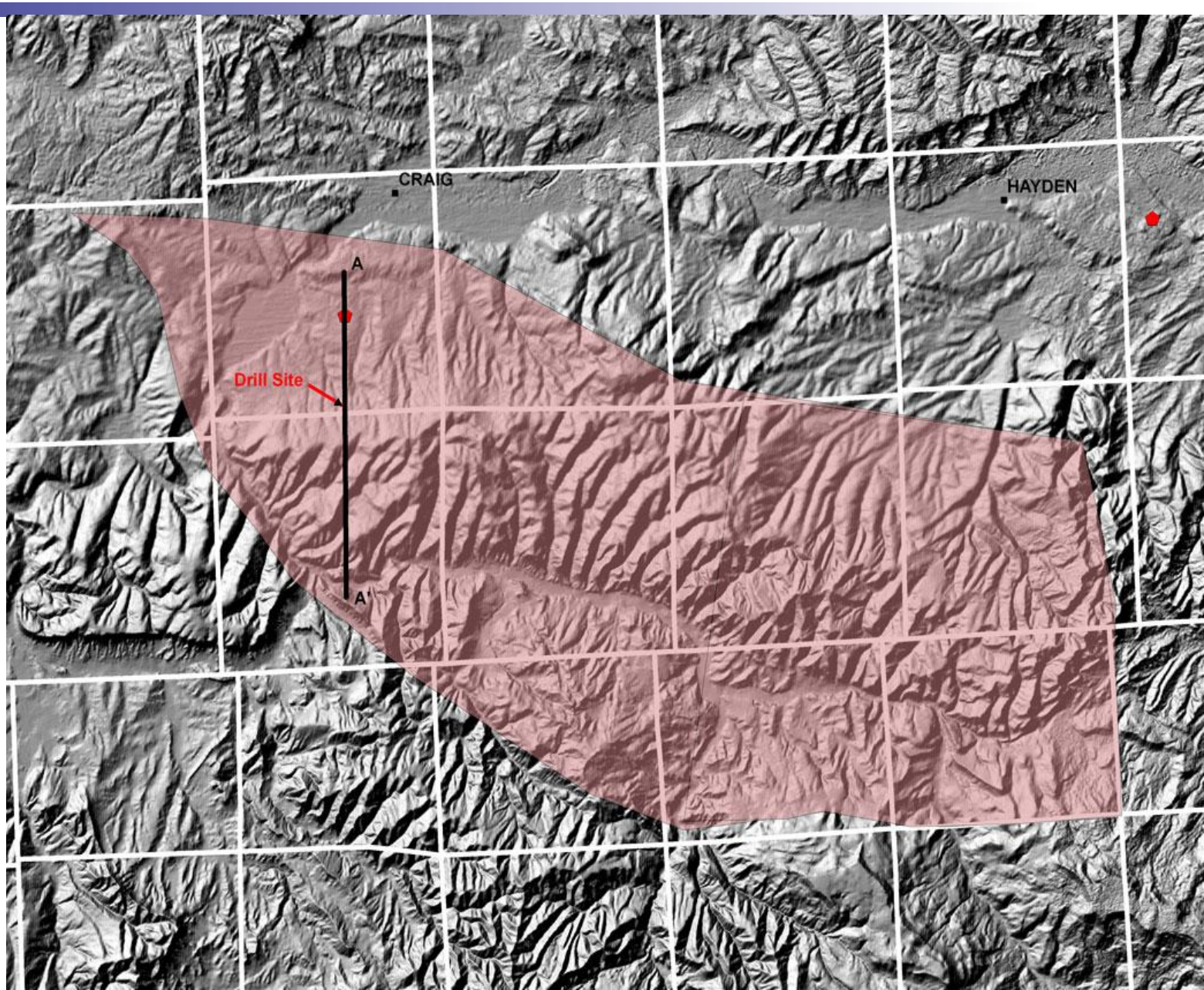
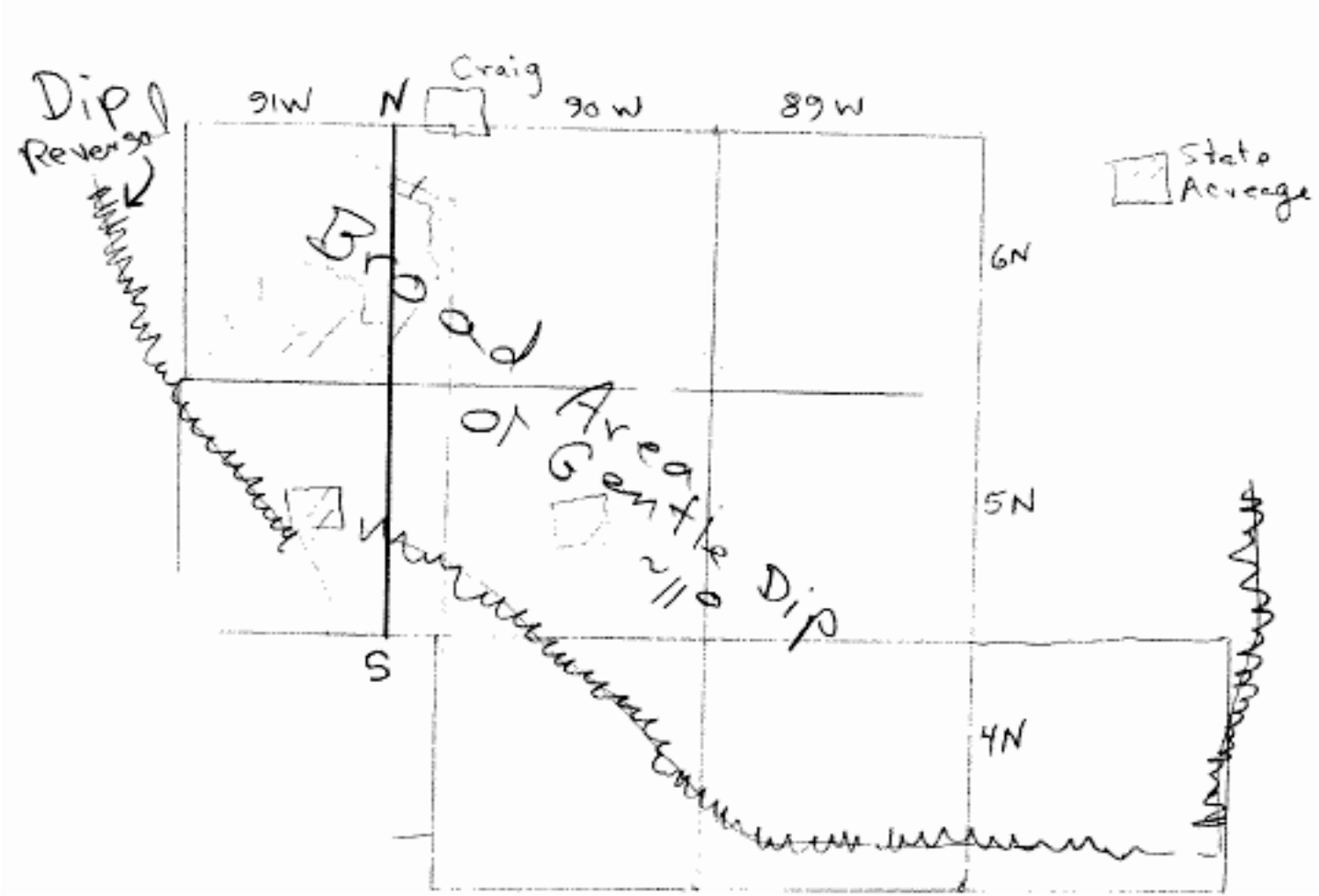


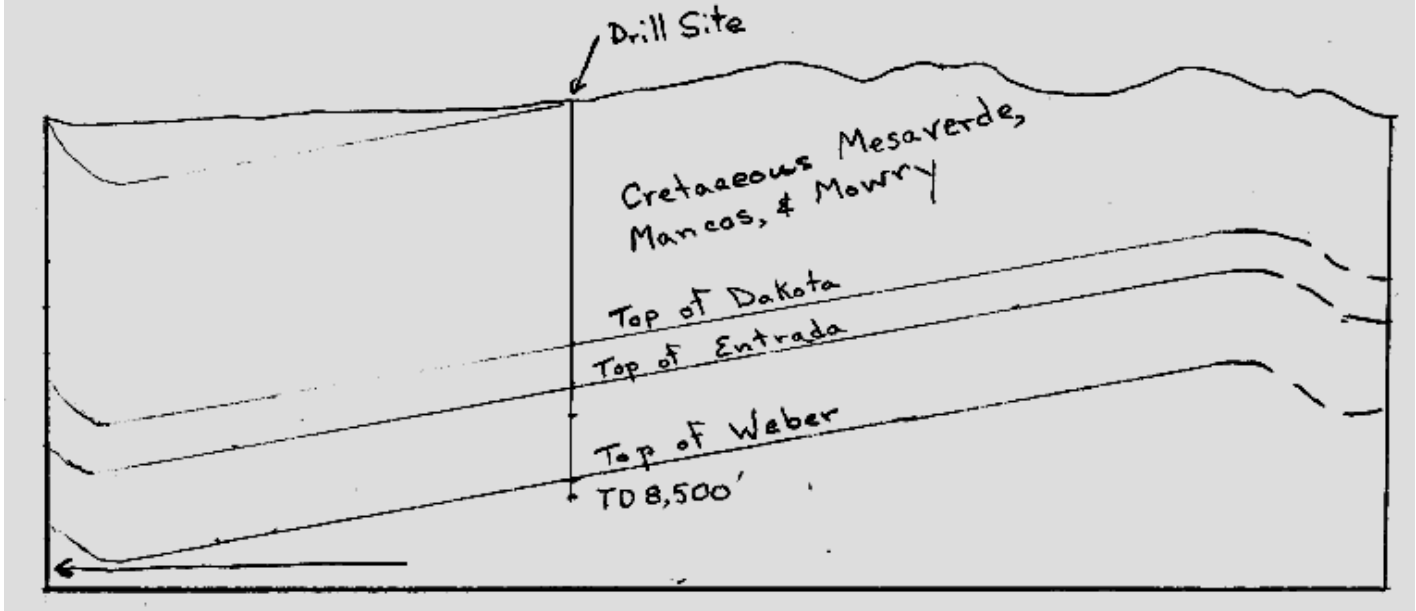
What do we know so far?

We then: developed simple conceptual models including 3-D



What do we know so far?

We then: developed simple conceptual models including 3-D and 2-D structural geology for initial model gridding and analysis



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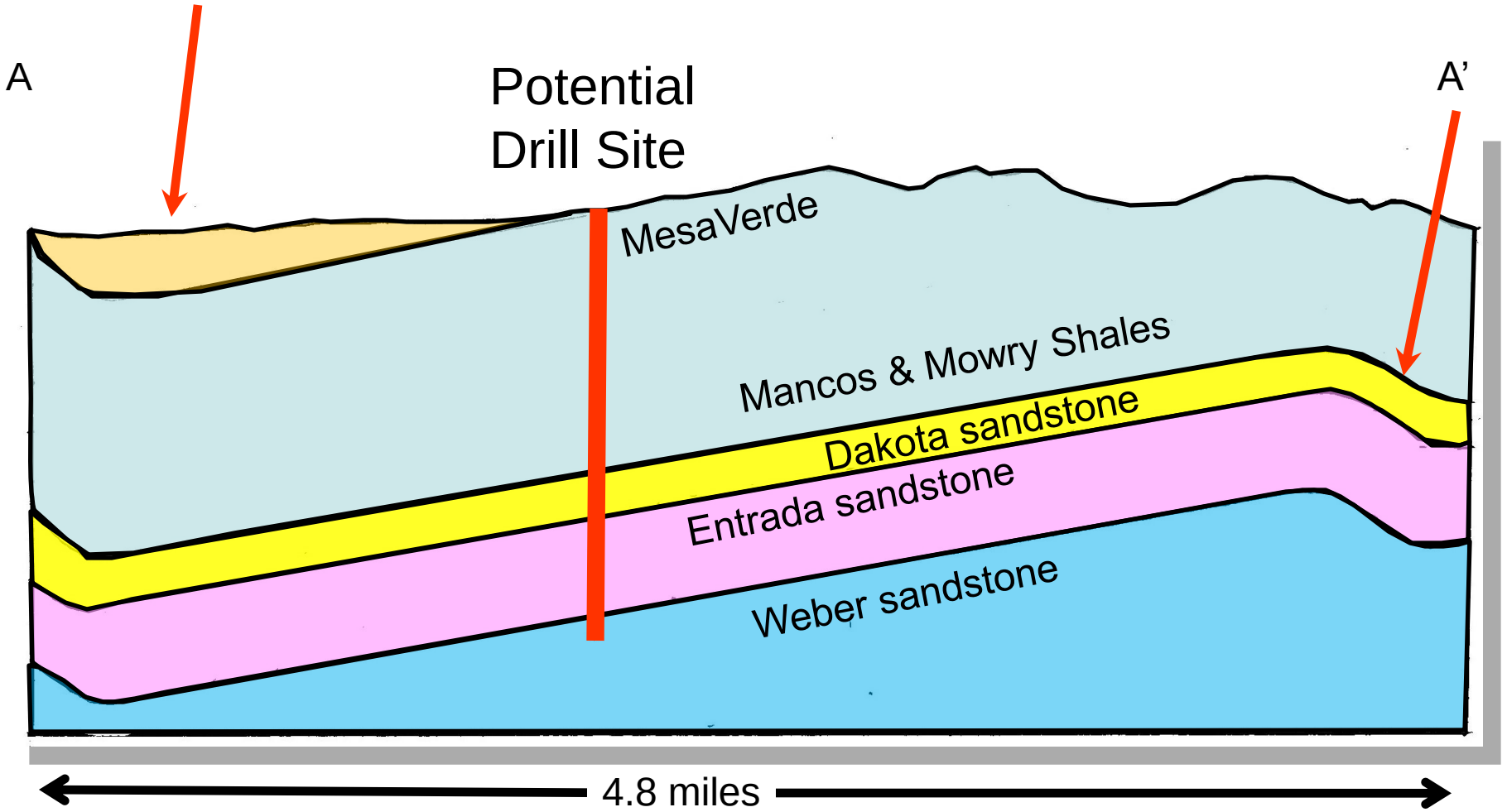

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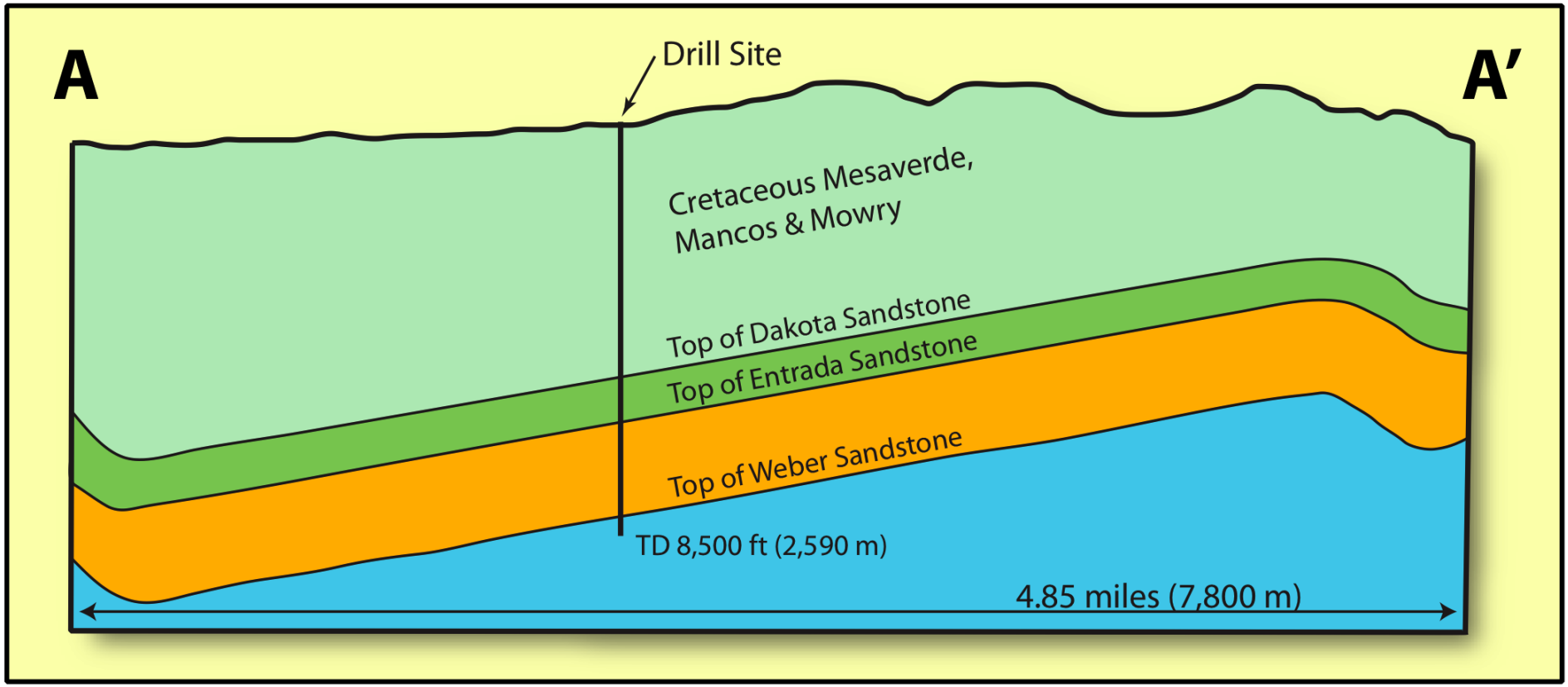
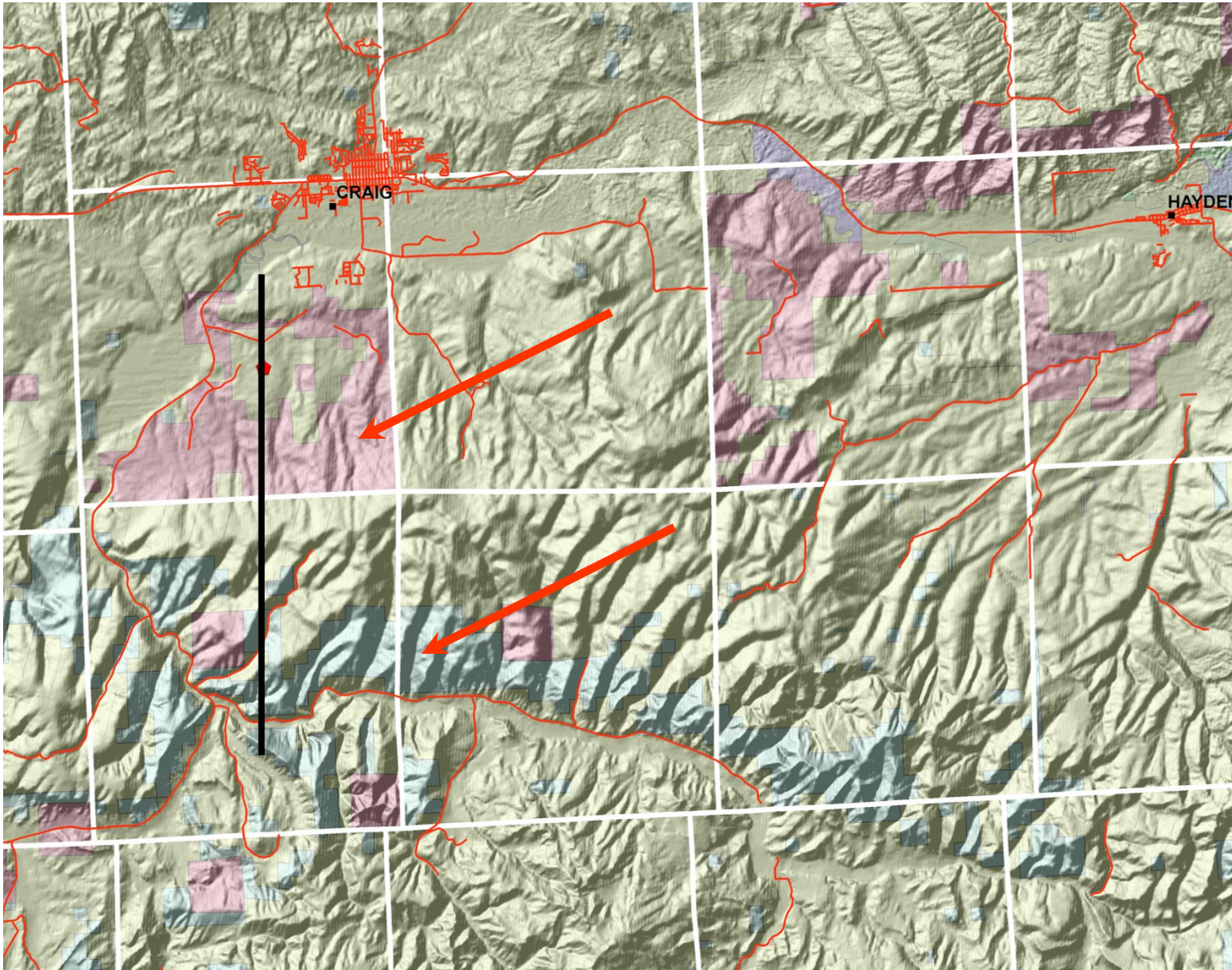
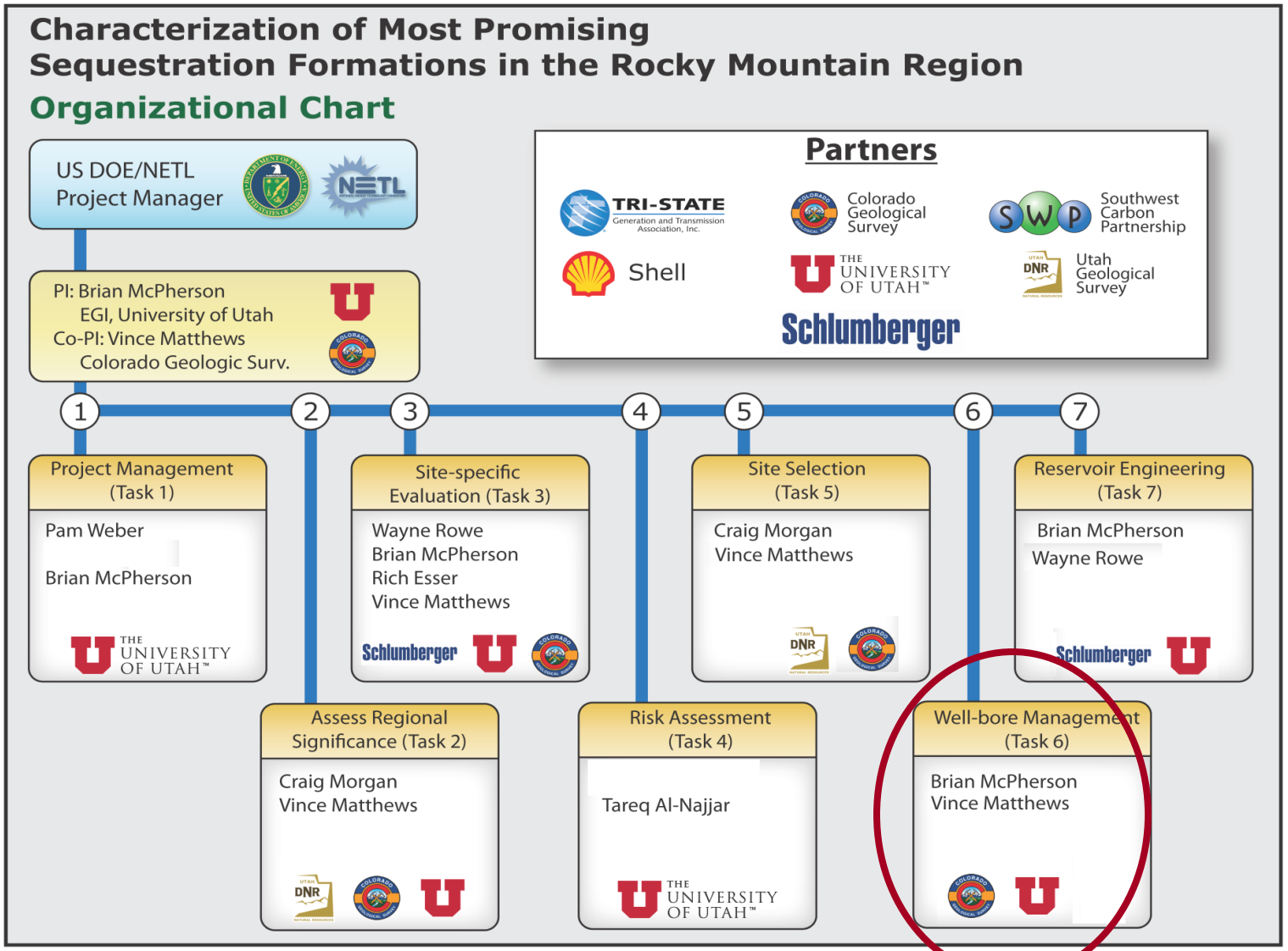


What do we know so far?

Land ownership will support project options and flexibility



Project Team and Approach



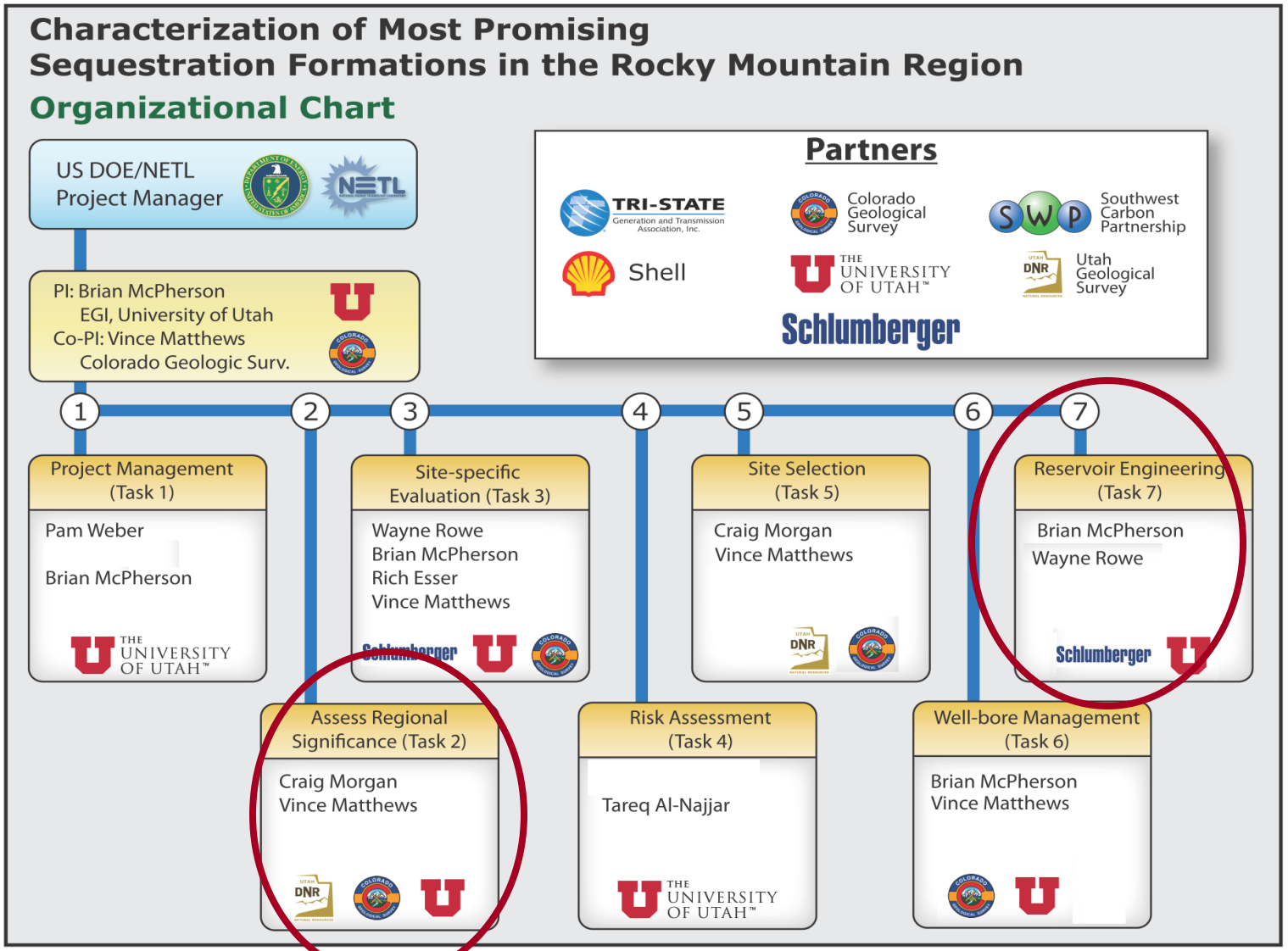
The Plan – Year 2

Drill Well

- Core Shale
- Core Sandstones
- Sample Waters
- Analyze Samples
- CO_2 Injectivity Experiments on cores

Continue Engineering Analysis & Reservoir Modeling

Project Team and Approach



The Plan – Year 3

Extend results to Colorado Plateau (Region)
Continue Reservoir Simulation:

- Storage Volume
- CO_2 Migration
- Potential Leakage Pathways
- Optimization Studies
- **Final Site Characterization Plan and Protocols**

Presentation Outline

- Major Goals and Context (Why)
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- Budget and Cost-Share

Budget

$4.8 million Project

$3.8 million Department of Energy

$1.0 million from Partners (20%)

Cost-Share by Partners

Tri-State Generation and Transmission- $300K

Shell Exploration & Production- $200K

Colorado Geological Survey- $162K

Schlumberger Carbon Management- $150K

University of Utah - $125K

Utah Geological Survey- $22K

Arizona Geological Survey- $19K

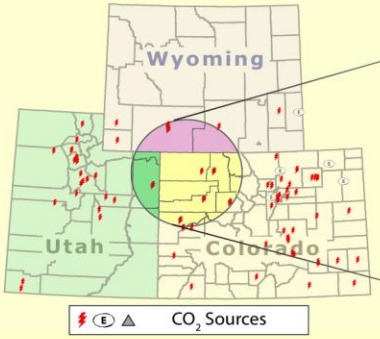
New Mexico Geological Survey- $19K

Project Summary

1.0 Project Management (Plan, Organize, Meetings, Finanacials, Prog. Risk, Outreach/Eduction, Permitting)

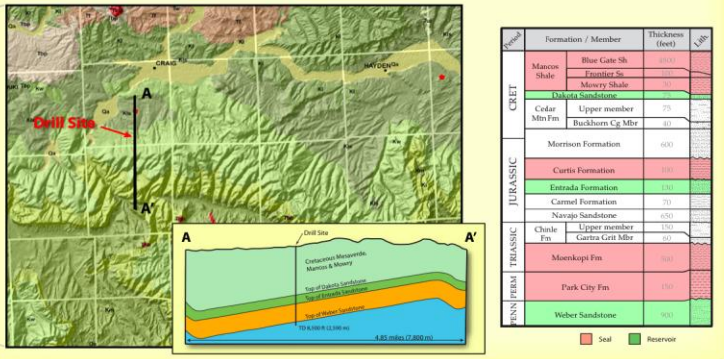
2.0 Regional Significance of Dakota, Entrada & Weber

Review available data (logs, studies, seismic) to determine capacity and injectivity (sustain 30 MMT of CO_2)



3.0 Site Specific Evaluation of Dakota, Entrada & Weber

Conduct field operations (drill/core well, fluid analyses). Use lab and field data to refine capacity, injectivity and containment.



4.0 Conduct Risk Assessment

Create risk registry, identify site-specific FEPs, evaluate mitigatation strategies and any cost-savings.

5.0 Develop Site Selection Criteria

Compile list of selection criteria based upon site-specific characterization results

6.0 Well bore management

Use data from Task 4.0 to prepare a management plan that will prevent leakage of CO_2 through artificial penetrations (well bores, mines, etc).

7.0 Maximize CO_2 Injection & Uses of Produced Fluids

Develop an engineering plan to optimize well placement for the region to maximize the amount of CO_2 storage based upon results of the characterization study. Develop a produced fluid disposal plan that will integrate mitigation strategies with respect to reservoir pressure stabilization.

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